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20–24 April 2009

Scalloway, Shetland Isles, UK

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Executive summary

The long term aim of the Working Group (WG) is to provide an assessment of the status of crab stocks within the ICES area with an emphasis on the biology and life history underlying the stock assessments and, if necessary, provide management advice. This process involves the cataloguing of data and methods, the discussion of biological information such as growth and migratory movements, and a review of stock assessment techniques and their application. At present there is little coordination and oversight of national monitoring and assessment programmes. The WG recognised that much work has to be done before the long term objective of providing peer reviews of assessments of the status of crab stocks within the ICES area can be achieved. National assessments of various crab species are undertaken currently, but a variety of approaches is taken and not all species and member countries are represented at the WG.

A review of trends in fisheries data such as CPUE & LPUE was carried out and it was clear that there is significant variation in the level of data collected both across regions for particular species and across species. In particular there is little or no accurate information on fishing effort for some fisheries that makes undertaking an assessment of the status of the stock very difficult. The WG agreed that it should aim to provide reports with all relevant fisheries statistics and assessments in a similar format for all crab species exploited in the ICES region. Much work remains to be completed if the stock structure of the various crab species is to be elucidated. At present genetics studies, larvae distributions in relation to local hydrography and adult tagging studies all provide some information in relation to defining stock structure, but management units are determined primarily on a pragmatic basis in which local geography rather than known stock structure is the most important component. It was clear that international assessments of fisheries data were required where vessels of more than one nation are exploiting the fishery. For *Cancer pagurus* an initial discussion was held to discuss a joint assessment of the Channel stocks fished by UK, French, Belgian and Channel Islands vessels. Similar joint assessments need to be carried out by UK and Irish scientists for the Malin stock of *Cancer pagurus*.

A review of growth data for the various crab species highlighted that many of the growth parameters used in the stock assessments were calculated from tagging studies conducted many years ago, and that growth parameters derived for one area were often used for assessments in other areas. However the WG were encouraged that many new tagging studies particularly on *Cancer pagurus* had been started recently, including the use of data storage tags (DSTs), which should provide new information both on growth rates and on movements of crabs which would inform studies of crab stock structure.

The WG discussed a new piece of European legislation (EC Directive 2006/88) in which three crustacean viral diseases (causing White Spot Disease, Yellowhead Disease and Taura Syndrome) have recently been listed, and highlighted the susceptibility of several European crustacean species to White Spot Disease. The WG also discussed the observed high prevalence of disease in juvenile *Cancer pagurus* and the implications for survival and recruitment to the fishery of young cohorts.

In future the WG needed to develop an ecosystem-based approach to crab stock management, and consider wider issues such as the impact of introduced crab species and the impact of climate change on crab distribution and abundance.

1 Introduction

1.1 Background to the Working Group

The Working Group on the Biology and Life History of Crabs [WGCRAB] was formed in 2006 as a successor to the Study Group on the Biology and Life History of Crabs [SGCRAB]. The first meeting of the Study Group on Crab met in Jersey, UK, in 1993 to review progress on the research and fishery management of two commercially important Majidae species, the spider crab (*Maia squinado*) and the snow crab (*Chionoecetes opilio*), fished on the two sides of the Atlantic and in the Pacific. The Study Group (SG) recognised the need for more intensive coverage of the life history characteristics of the two species, and a better geographic representation of crab biologists. This led to a second meeting at La Coruña, Spain, which reviewed new information available on the life history and fishery management of the spider crab and *Chionoecetes* species (*opilio*, *bairdii*, *tanneri*). It was recommended that the remit of SGCRAB should be enlarged to include other commercially important crab families (notably portunid and cancrid crabs) that are not covered by ICES Assessment Working Groups or Study Groups. Subsequent meetings of SGCRAB were convened in Brest, France in May 1998, in Copenhagen, Denmark in March 2001, in Tromsø, Norway in June 2003 and in Galway, Ireland in May 2005 respectively.

Following a meeting by correspondence in 2006, the SG acknowledged that the Terms of Reference of the Group had evolved over recent years to encompass the compilation of biological information and fisheries data which are the building blocks of stock assessments for crab species exploited within the ICES regions, and recommended therefore that the Study Group should become a Working Group. ICES accepted this recommendation and the Working Group (WG) met for the first time in Lowestoft, UK in April/May 2007.

Crab species represent some of the most valuable fisheries within the ICES area, and fishing effort has been increasing in most of these fisheries in recent years requiring robust assessment of the status of stocks and appropriate management advice. At its meeting in Lowestoft, UK in 2007 the WG agreed that its long term aim should be to provide an assessment of the status of crab stocks within the ICES area and, if necessary, provide management advice. At present there is little coordination and oversight of national monitoring and assessment programmes, and the WG agreed that it should now meet annually with Terms of Reference that move towards the long term aim of provision of advice on the status of crab stocks.

It was agreed that this process should involve the cataloguing of data and methods, the discussion of biological information such as growth and migratory movements, and a review of stock assessment techniques and their application including biological reference points in order to share best practice across the various crab stocks in the ICES region. Ultimately the objective is to provide peer review of assessments and to ensure that international assessments are undertaken for stocks which are exploited by more than one country and which currently are assessed on a national basis only. It is expected that those international assessments would involve an ecosystem approach to the management of stocks.

The WG recognised that much work has to be done before the long term objective of providing peer reviews of assessment of the status of crab stocks within the ICES area can be achieved. National assessments of various crab species are undertaken currently, but a variety of approaches is taken and not all species and member countries are represented at the WG. The aim therefore of the next few meetings is to collate information on long term trends in key indicators of the status of crab stocks, review assessment methodologies, synthesise approaches and identify gaps in information and knowledge. This process was started at the WG in Brest, France in 2008 and this report describes further progress made at the WG in Shetland, UK in 2009 towards the long term aims of the WG.

1.2 Terms of Reference

The Working Group on the Biology and Life History of Crabs [WGCRAB] (Chair: Julian Addison, UK) will meet in Scalloway, Shetland, UK, on 20–24 April 2009 to:

a) Define and report on stock structure / management units for crab stocks

b) Compile data on landings, discards, effort and catch rates (CPUE) and provide standardised CPUE, size frequency and research survey data for the important crab fisheries in the ICES area

c) Collate and evaluate all fisheries data from the various national programmes for the Western Channel and Malin *Cancer pagurus* stocks

d) Review data availability for each species/stock in relation to the requirements of the currently available assessment methods for crabs

e) Review growth rate data and other biological information that is required for providing standardised indices and for analytical assessments

f) Review information on the incidence/prevalence of disease in crab fisheries and review the extent to which bitter crab disease might affect recruitment.

1.3 List of participants at the WGCRAB 2009 meeting

A complete list of participants is given in Annex 1 of this report.

2 Progress in Relation to the Terms of Reference

2.1 ToR a: Define and report on stock structure / management units for crab stocks

2.1.1 Background

The first critical stage in undertaking a stock assessment is to identify the structure of the stocks in relation to the geographical distribution of the fishery, following which appropriate management units can be identified. Last year's WG meeting reviewed the current management units for crab species exploited in the ICES region, and considered the criteria used to define those management units. Existing management units for most exploited crab species are based on a pragmatic composite of fishery and geographical factors and not biological stock units. Whilst, for example, some management units for snow crab may be based on bottom topography and for brown crab on lack of movement between areas by tagged animals and local hydrography, in general management units are based on the distribution of local fisheries and geographical boundaries. Whilst this is an acceptable approach to defining management units in the absence of strong biological evidence, the WG agreed that more consideration should be given to biological factors such as larvae dispersal and recruitment mechanisms, allied to a greater understanding of relevant hydrography. Tagging studies provide information on the movement and dispersal of adult crabs, but larvae dispersal and local hydrography are expected to be key determinants of stock structure. Modern genetic approaches have provided an opportunity to answer key questions on stock structure, but to date have not provided the step change in understanding that these techniques promise, possibly because for most species, multiple fisheries may simply be one large stock. There is an obvious need therefore to consider international assessments and not national assessments in circumstances when clearly a single stock is being exploited by more than one country.

The WG considered a number of genetics studies of exploited crab species, and the current available knowledge of larvae dispersal in relation to hydrography, and considered what future work in these areas might bring significant advances in our understanding of crab stock structure and hence the spatial scale on which to manage stocks.

2.1.2 Genetics studies

2.1.2.1 Brown crab (*Cancer pagurus*)

The results of a recently published paper on genetics of *Cancer pagurus* in Swedish waters (Ungfors *et al*., 2009) were presented to highlight the problems of interpreting genetic structure of *Cancer pagurus* in relation to stock management. Stock structure in the Kattegat and Skagerrak was investigated using eight microsatellite DNA loci. Replicate samples, collected 4–6 years apart, were derived from the Kattegat (Grove Bank, 57°N) and the Skagerrak (Lunneviken, 59°N), plus a geographical outgroup sample from the Norwegian Sea (Midsund, 62°N). Genetic differentiation among samples, estimated as global $F_{ST} = 0.002$, was significant ($p = 0.03$) when the statistical test was based on allele frequencies, but not when based on genotype frequencies. Moreover, all single- and multilocus pairwise tests between samples were non-significant. An analysis of molecular variance, AMOVA, did not reveal significant differentiation between spatial (Kattegat vs. Skagerrak) or temporal (2001/2002 vs. 2006/2007) groups of samples. Power analysis suggested that the loci and sample sizes employed conferred a power of > 90% of detecting even low (true $F_{ST} = 0.002$) levels of population structure.

This observed low spatial and temporal genetic structure is typical of studies on *Cancer pagurus* and might be explained by either or both of (i) high levels of contemporary gene flow in the area attributable to adult migration or larval dispersal or both factors taken together, and (ii) patterns of historical gene flow persisting among recently founded large populations.

In Irish Waters on the Malin Shelf, a similar study using microsatellites failed to find any differences in the Malin area. Together with the results from tagging and recruitment studies, this had led to the conclusion that *Cancer pagurus* in the Malin Shelf area constituted a single population. A wider study on genetic structure of *Cancer pagurus* (McKeown and Shaw, 2008) has highlighted some significant genetic structure at fine geographical scales, but these results are difficult to reconcile with other information on larvae stage duration and adult movements for this species.

2.1.2.2 Other species

Microsatellite markers for snow crab (*Chionoecetes opilio*) revealed an absence of significant genetic structure along the west coast of Greenland and within Atlantic Canada from southern Labrador to Nova Scotia (Puebla *et al*., 2008). A genetic break was identified between Greenland and Atlantic Canada showing that genetic structure can develop within seas despite the occurrence of very long planktonic larval stages. No genetic difference has been observed between Norwegian snow crab and eastern Canada and it has been postulated that the appearance of this species in north European waters may have been achieved by migration along the north Siberian coast following warming of Arctic seas in recent times.

Genetic studies had found no differences between red king crab (*Paralithodes camtschaticus*) in Russian and Norwegian waters although there were some differences between the Barents Sea and the original area from which they were introduced 30 years previously.

No information on genetic structure of other species of crab exploited in the ICES regions was available at the WG.

2.1.3 Larvae dispersal in relation to hydrography

The WG considered that the lack of genetic heterogeneity across wide geographical areas for most crab species was a consequence of significant adult movements but primarily because of the long pelagic larval phase duration and the possible role of local hydrography and how it affects larval dispersal. So whilst the WG encouraged further genetics studies, it agreed that current emphasis should be on filling key gaps in our understanding of larvae behaviour in relation to hydrography. For example, little is known of the effects of temperature on larvae behaviour, or whether vertical movement of larvae is a reaction to currents or simply to avoid predators. It might, for example, be worthwhile to undertake hydrographical modelling to predict where larvae might go and hence where you might go to look for significant genetic differences.

There are likely to be particular problems where crab species have been introduced into new areas or where the range of the species may have changed due to global warming affecting fecundity, reproduction rates, and size at maturity. A basic knowledge of biology and an ecosystem view were essential particularly when introduced populations could have totally different growth characteristics from "home" populations.

Finally the WG acknowledged that increased knowledge of genetic structure of populations, and the potential identification of metapopulations of crab populations where sub-populations are linked by larvae dispersal still might not provide clear evidence on which to base management units. As before, management units might still need to be based on a high level of pragmatism. Local genetic differences would warn us to guard against local depletions, but it may simply not be practical to manage crab stocks at a fine geographical scale.

2.2 ToR b: Compile data on landings, discards, effort and catch rates (CPUE) and provide standardised CPUE, size frequency and research survey data for the important crab fisheries in the ICES area

2.2.1 Background

Presentations and/or information were received on fisheries for *Cancer pagurus* in UK, Ireland, France, Norway and Sweden, on velvet crabs (*Necora puber*) in the UK, on spider crab (*Maja brachydactyla*) in Ireland, on *Paralithodes camtschaticus* in Norway and on snow crab (*Chionoecetes opilio*) in Canada. These presentations are summarized in the following sections. The presentations and subsequent discussions highlighted that collation of fisheries data and subsequent stock assessments for crab species are undertaken on a national basis, and indeed separately for the various administrations in the UK, and often in different ways in the various countries. It was agreed therefore that the Working Group would be the appropriate forum in which to ensure that data are collected, standardised and analysed in the same way, initially across the various countries and ultimately by crab stock where such stocks transcend national boundaries. In this report the data are presented in the format provided by the various contributors, but the WG agreed that from 2010 onwards it would move towards presenting the data from various countries on the various species in a standard format.

2.2.2 *Cancer pagurus* fisheries

2.2.2.1 England and Wales fisheries

Landings and effort statistics for the England and Wales fisheries for brown crab (*Cancer pagurus*) have been collected officially since 1983 but data have been generally of poor or variable quality. Total landings may reasonably reflect trends, but are thought to have been generally under-recorded. Effort data tend to be poor, being incomplete and sometimes inaccurate. A brief account of data quality and the effects of recent changes to the reporting system following the introduction of EU logbooks (>10m vessels) and the national Restrictive Shellfish License Scheme, RSLS (<10m vessels) was presented at the WG in 2007 (ICES, 2007).

Landings as well as "days-fished" and "landings per day" as crude measures of effort and LPUE, were examined for the under and over 10m fleets separately in each of the 6 stock management units (SMU) suggested for *Cancer pagurus* fisheries around England and Wales.

Southern North Sea

Landings increased steadily until 2003 when a sharp decline was observed. However, there were known problems collecting fisheries data in both 2004 and 2005 and it is possible that significant under-reporting took place in these years. However, there is also a similar decline in LPUE, which may suggest declining stock abundance (Figure 2.1). Although the >10m fleet contributed the major part of the landings for the 1990's onwards, due mainly to the introduction of larger and vivier vessels developing offshore fisheries, the bulk of the effort in the fishery appears to be expended by the <10m fleet and this is reflected in the much lower LPUE values for the <10m fleet than the >10m vessels. However, these effort data are based on "days fished" and do not take account of the number of pots set or hauled. Larger vessels work far more gear than smaller ones and their LPUE may be over-estimated. The effect of the introduction of the mandatory returns under new licensing regulations for <10m vessels in 2006 is apparent, producing increases in both recorded landings and effort for that fleet.

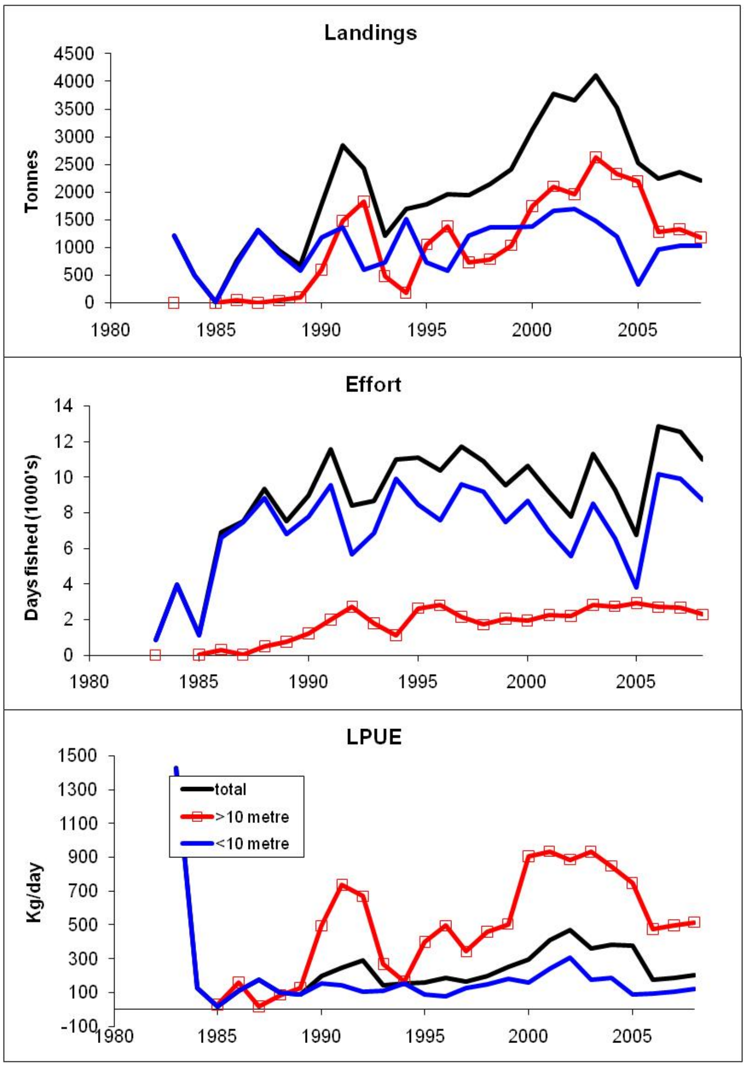


Figure 2.1. Landings, effort and LPUE for the Southern North Sea brown crab (*Cancer pagurus*) fishery.

Central North Sea

Landings have increased steadily from a low point of 300 tonnes in 1991 to over 2400 tonnes in 2007. Landings doubled in 2006, possibly due in part to the introduction of mandatory returns for the <10m sector, although there was also a comparable rise in landings by the >10m fleet. There has been a concomitant slow increase in LPUE for both fleets until 2005 (Figure 2.2). In 2006 there was a dramatic increase in LPUE for the >10m fleet, but a small fall for the <10m fleet. Overall the days fished of the >10m fleet has remained fairly constant with larger fluctuations in the <10m fleet where switching of target species is more prevalent. The effect of mandatory returns for the <10m fleet has had an obvious effect on reported effort from 2006.

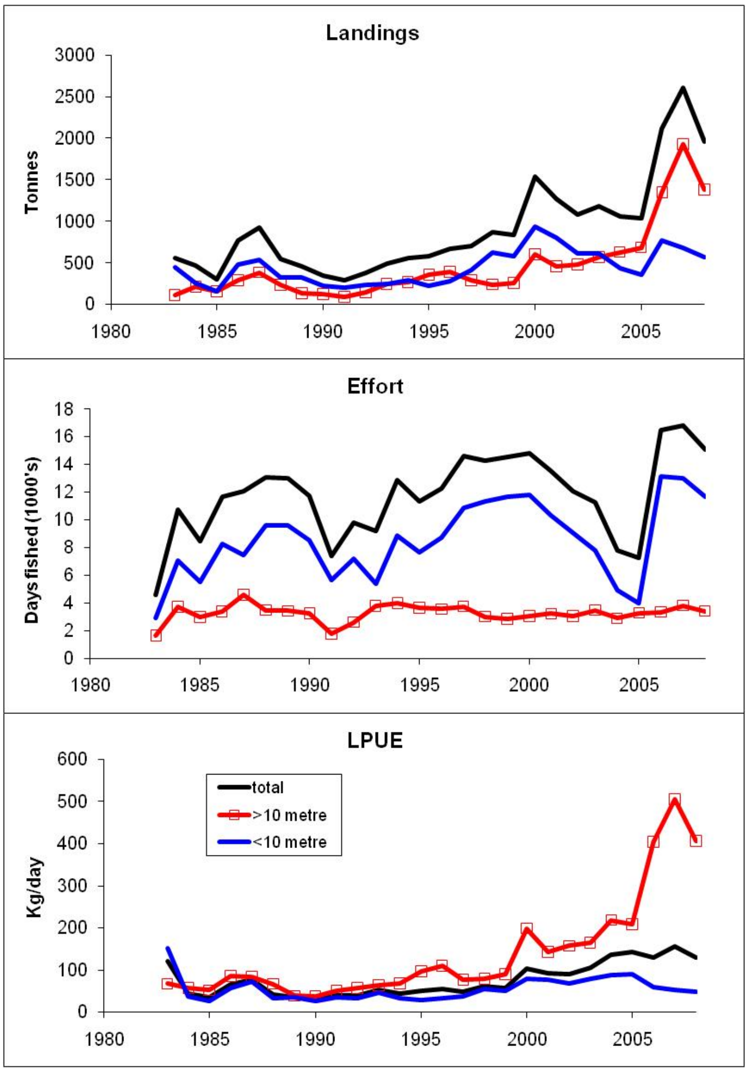


Figure 2.2. Landings, effort and LPUE for the Central North Sea brown crab (*Cancer pagurus*) fishery.

Eastern Channel

The Eastern Channel has supported a relatively small fishery historically with peak landings in 1994 of 800 tonnes, followed by a steady decline in both <10m and >10m sectors to 200 tonnes in 2007, around 150 tonnes of which was taken by a few, larger boats (Figure 2.3). Days fished also appears to have declined over the same period. Whilst LPUE for both sectors combined shows no discernable trends, LPUE for the >10m fleet has declined slightly since 2001, although not to the low levels observed in 1998 or the late 1980s. LPUE for the <10m sector appears to have declined through the late 1990s and early 2000s.

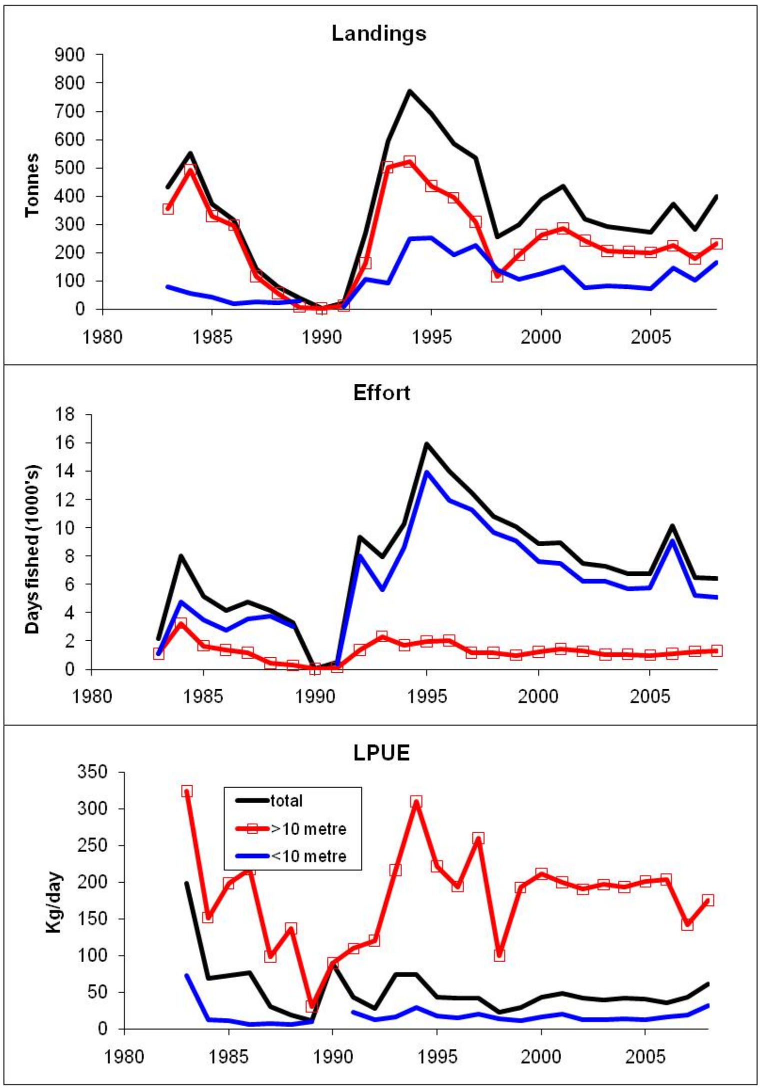


Figure 2.3. Landings, effort and LPUE for the Eastern Channel brown crab (*Cancer pagurus*) fishery.

Western Channel

Landings have typically fluctuated between 3000 and 6000 tonnes per annum over the last two decades with a marked peak in the late 1990s when they increased to over 10000 t (Figure 2.4). Since then they have declined in two steps and are now around 4000 t. From 1998 to 2005 effort (in days fished) also appears to have declined with little difference between the >10m and <10m sectors. Since 2006, effort for the <10m fleet exhibits a five-fold increase. The >10m fleet, which is well represented in this region, exhibits a much higher LPUE than the <10m sector. However, this takes no account of the number of pots fished and the increasing trends of fishing multiple sets of gear. The effect of the introduction of mandatory returns of landings and effort data for the <10m fleet is again evident and has led to the marked drop in total LPUE (combined fleets) in 2006.

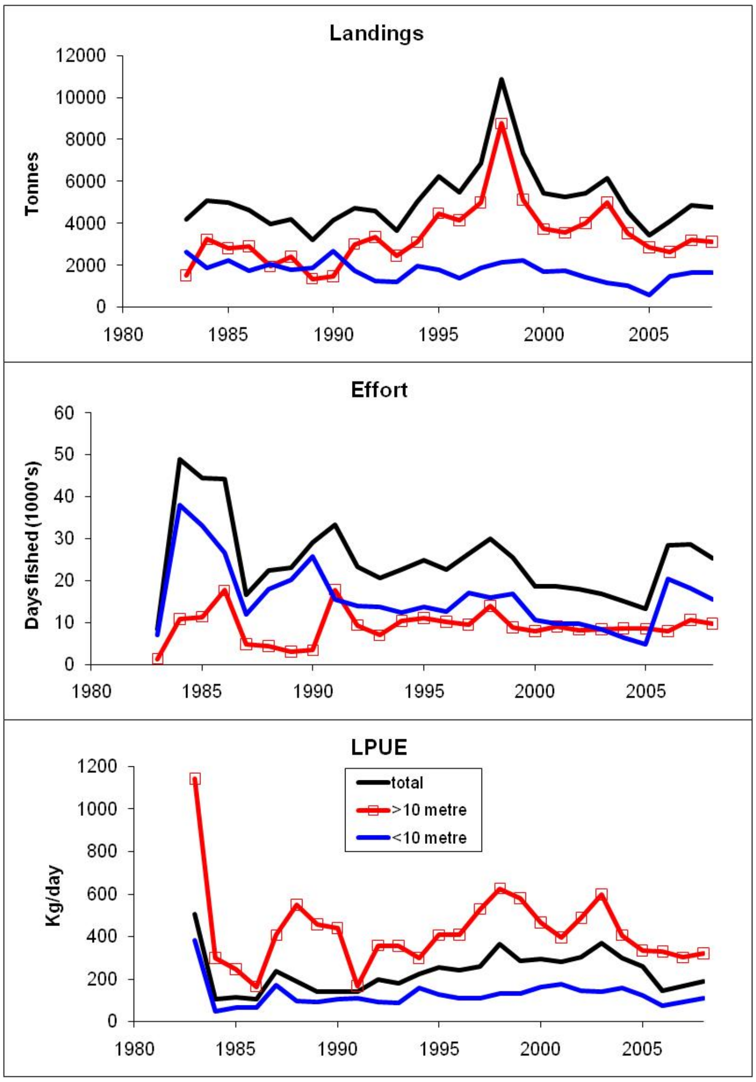


Figure 2.4. Landings, effort and LPUE for the Western Channel brown crab (*Cancer pagurus*) fishery.

Celtic Sea

After a decline in landings from 1000 tonnes per annum in the late 1980s to around 300 tonnes in the mid-1990s, there has been a recovery in landings to over 1400 tonnes per annum, generated mostly by the >10m fleet (Figure 2.5). LPUE appeared to rise from around 100kg day^{-1} in 1990 to approximately double that by 2005. However, the <10m fleet is very strong in this region and there is almost certainly a strong element of under-reporting of <10m catch and effort running up to the introduction of new regulations for mandatory returns in 2006 when reported landings by this sector were nearly 500 tonnes compared with only 5 tonnes the previous year! This explains the sharp drop in LPUE in 2006.

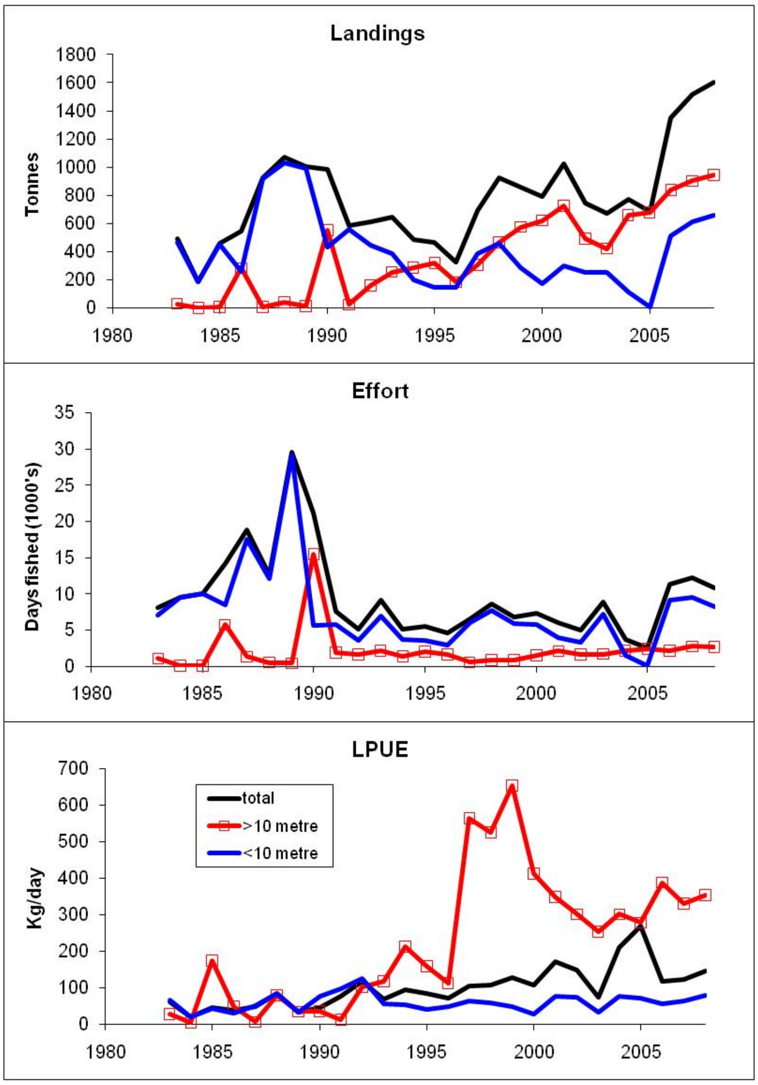


Figure 2.5. Landings, effort and LPUE for the Celtic Sea brown crab (*Cancer pagurus*) fishery.

Irish Sea

Crab landings in this region have been low compared with other areas and are almost exclusively by <10m boats around the Welsh coast (Figure 2.6). The seven-fold increase in recorded landings (37 to 244 tonnes) and effort between 2005 and the introduction of new licensing regulations in 2006 suggests that the official database records were unreliable for this area before that year.

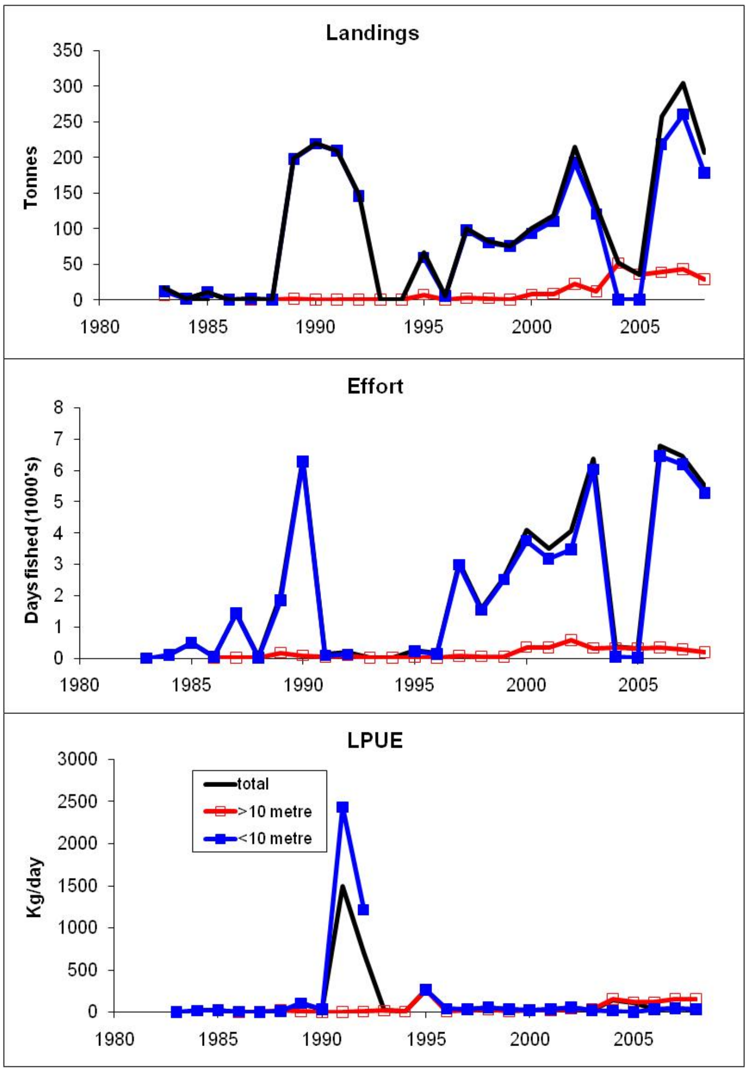


Figure 2.6. Landings, effort and LPUE for the Irish Sea brown crab (*Cancer pagurus*) fishery.

Seasonal trends

Monthly landings, effort (days fished) and kg day^{-1} for each area show the same basic pattern in most areas with the highest catch rates in the autumn/early winter period (see an example for the Western Channel in Figure 2.7). The seasonal pattern of fishing effort tends to peak earlier than landings and this may reflect greater activity of smaller vessels during fine weather in the summer months. As LPUE is a function of landings and effort it tends to be lower during the summer, possibly due to high activity by smaller vessels and highest late in the year, when small vessels will be less active and the fishery is primarily prosecuted by large vessels.

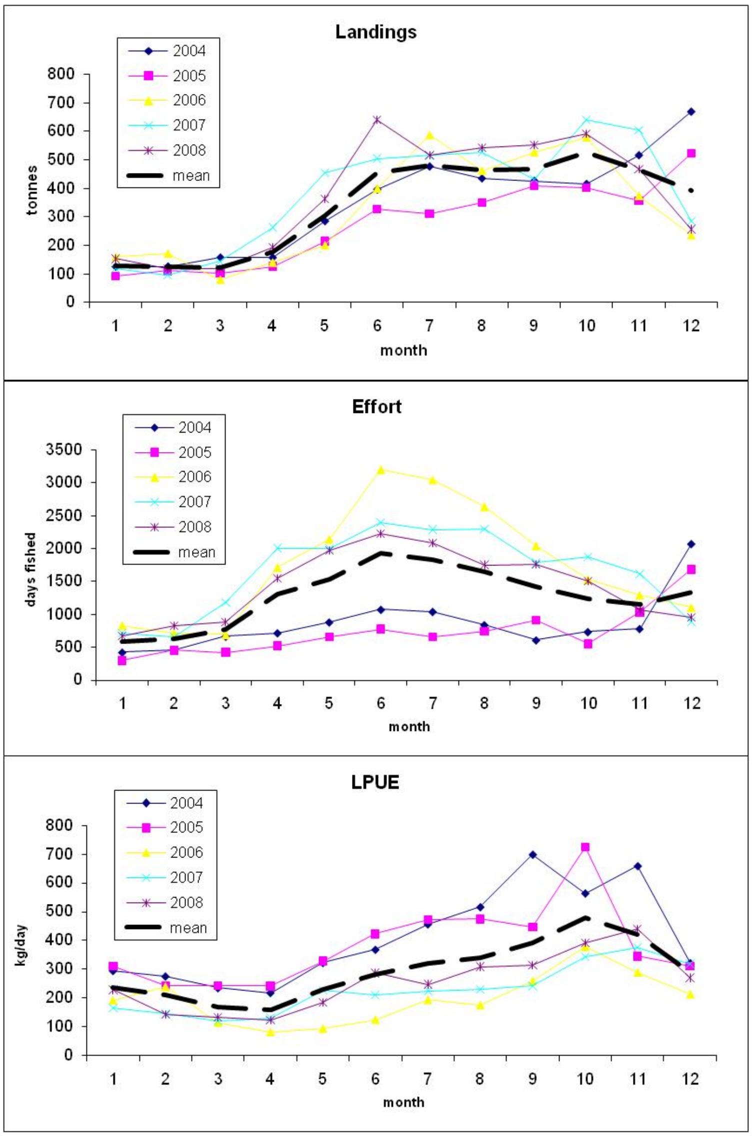


Figure 2.7. Seasonal trends in landings, fishing effort (days fished) and LPUE for the Western Channel brown crab fishery from 2004 to 2008.

2.2.2.2 Scotland

2.2.2.2.1 National data

The Scottish creel grounds are divided into 12 areas for the assessment of crabs and lobsters. These areas are based on the previous district and creek system for reporting Scottish landings data, but have been revised to include two offshore areas – Papa, which lies to the west of Shetland, and Sule, which is to the north and west of Orkney and includes the Rona, Sulisker and Sule-Skerry banks. It is thought that crab stocks to the West of Scotland, South of the Hebrides are contiguous with the Malin Shelf stock to the North of Ireland, but how far north this stock extends is not currently known. Total brown crab landings in Scotland fluctuated between 6700 and 12 000 during 2000 to 2008 (Table 2.1). The main fishing areas for brown crab are the Hebrides, Sule, South Minch and Orkney; landings from these areas account for around 65% of the total. Landings from the offshore areas of Sule and Papa have increased since the mid to late nineties and in 2008 accounted for a further 28 % of the Scottish fishery. The majority of crabs fished in Scottish waters are landed in the third and fourth quarters of the year.

Brown crab landings length-frequency data are collected by Marine Scotland – Science for each of the main assessment areas. From the sampled data it seems that crabs landed from the west and north of Scotland are larger in size than those from the east coast with the majority of the crabs landed from offshore grounds being females. There is currently no catch per unit effort (CPUE) time series data for brown crab in Scotland. The length-frequency data are used to conduct a Length Cohort Analysis (LCA) for each area. To account for the differences in growth and length-weight relationships sexes are assessed separately. The results of LCA are used to calculate yield-per-recruit and biomass-per-recruit curves. Estimates of the von Bertalanffy growth parameters: asymptotic length (L_∞) and instantaneous growth rate (K) are made from Ford-Walford plots. Length-weight relationships are from Marine Scotland – Science (unpublished) market sampling measurements of length and weight (Table 2.2).

Table 2.1. Annual Brown crab landings (tonnes) in Scotland by creel fishery assessment area from 2000–2008. Data from Fisheries Management database.

Area	Year								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Clyde	155.4	86.7	53.8	57.0	21.0	39.6	198.2	250.3	213.7
East Coast	1097.8	855.3	529.1	426.5	369.5	405.9	830.4	884.2	866.9
Hebrides	1847.2	1831.4	1613.3	1452.9	1381.9	1730.0	2279.4	2340.0	1738.4
Mallaig	10.8	17.9	2.0	1.6	6.7	5.2	7.7	67.0	32.4
North Coast	713.1	614.9	497.1	793.4	318.2	814.3	435.8	513.8	348.7
Orkney	1510.2	1539.2	1498.6	1362.2	1309.5	1582.2	1467.9	1555.4	1187.3
Papa	684.7	694.8	771.9	785.2	463.5	454.1	838.2	798.0	764.1
Shetland	583.1	416.2	331.8	217.1	33.3	193.8	640.8	522.4	566.9
South East	480.9	148.1	96.8	23.0	129.0	166.0	273.8	281.8	325.5
South Minch	1119.0	1194.5	1251.9	1168.8	979.3	1421.3	1453.6	2324.5	1290.9
Sule	1238.9	788.2	952.4	865.6	1389.7	1357.9	1663.1	2026.1	1836.2
Ullapool	134.5	146.1	199.8	233.2	194.2	271.7	358.1	376.0	241.9
Outside Assess. Areas	112.5	155.7	110.6	185.4	104.9	205.5	120.5	26.5	32.1
Total	9688.2	8488.9	7909.2	7571.8	6700.6	8647.5	10567.6	11965.9	9445.0

Table 2.2. Biological parameters used in stock assessment for brown crab in Scotland.

		Growth parameters		Length-Weight relationship		Terminal group F	Mortality	Source
		K	L_∞	a	B	F	M	
	Males	0.197	220	0.000059	3.214	0.5	0.1	Chapman (1994)
	Females	0.172	220	0.000302	2.8534	0.5	0.1	Chapman (1994)
Shetland	Males	0.188	246	0.00008	3.166	0.406	0.242	Tallack (2002)
Shetland	Females	0.224	227	0.00024	2.895	0.174	0.256	Tallack (2002)

2.2.2.2.2 Shetland Isles

Landings of brown crabs (*Cancer pagurus*) have been recorded since 2000 through the submission of Shetland Shellfish Management Organisation logbooks. There have been fluctuations in the reported landings from a low of around 200 tonnes in 2002 and 2003 to a peak of almost 400 tonnes in 2006 (Figure 2.8). The landings in 2008 showed a decrease from the previous two years at 274 tonnes.

The majority of crabs landed in Shetland are processed by one local factory and the fishery is largely dependent on this business. The processing capacity of the factory imposes certain limitations on the landings in Shetland. There have been poor market conditions for brown crabs in 2008, which have resulted in processors limiting the amount which vessels can land, and some boats have even moved over to the velvet crab fishery while the market conditions remain unfavourable.

The changes in effort over the data collection period have shown similar trends to the landings data, although the scale of change has been slightly different (Figure 2.8). This resulted in an initial period of relatively stable LPUE of around 0.7 kg/creel between 2000 and 2002, followed by an increase to almost 1 kg/creel from 2004 to 2006 followed with a slight reduction in LPUE to around 0.8 kg/creel in 2007 (Figure 2.8). Values for 2008 showed an increase to around 0.9 kg/creel.

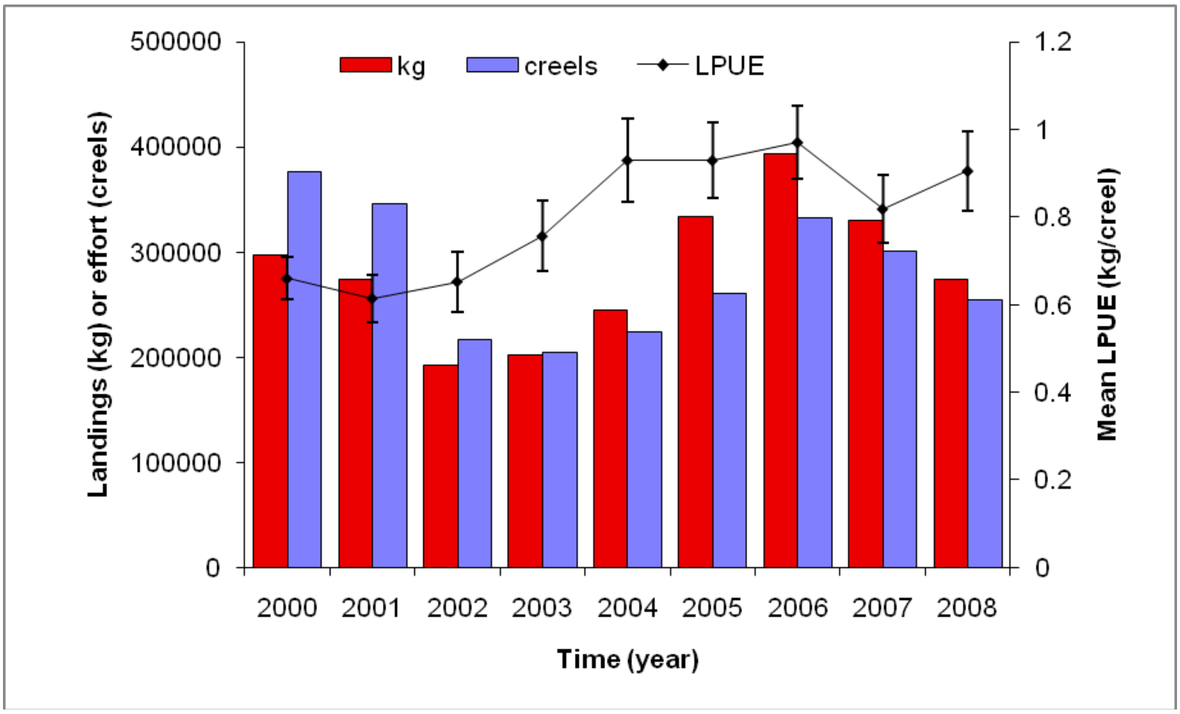


Figure 2.8. Total landings of brown crab (kg), total creels catching brown crabs and the average LPUE from SSMO logbook data with 95% confidence intervals shown.

A generalised additive model was used to further examine trends in LPUE. All four explanatory variables (year, month, vessel, area) significantly improved the fit of the model and were retained in the GAM (Figure 2.9). Long term trends indicate that LPUE has increased over the reference period (2000 to 2008), this increase has stabilised somewhat since 2006. Seasonal effects indicate that LPUE is relatively constant during the first nine months of the year, with a slight peak in September and lower values in November and December. As in the previous assessments there were large between vessel variations which add to the model, but which have not been explored further. In the first two stock assessments (Anon, 2005; Mouat *et al*., 2006) there were more marked spatial differences in brown crab LPUE around Shetland.

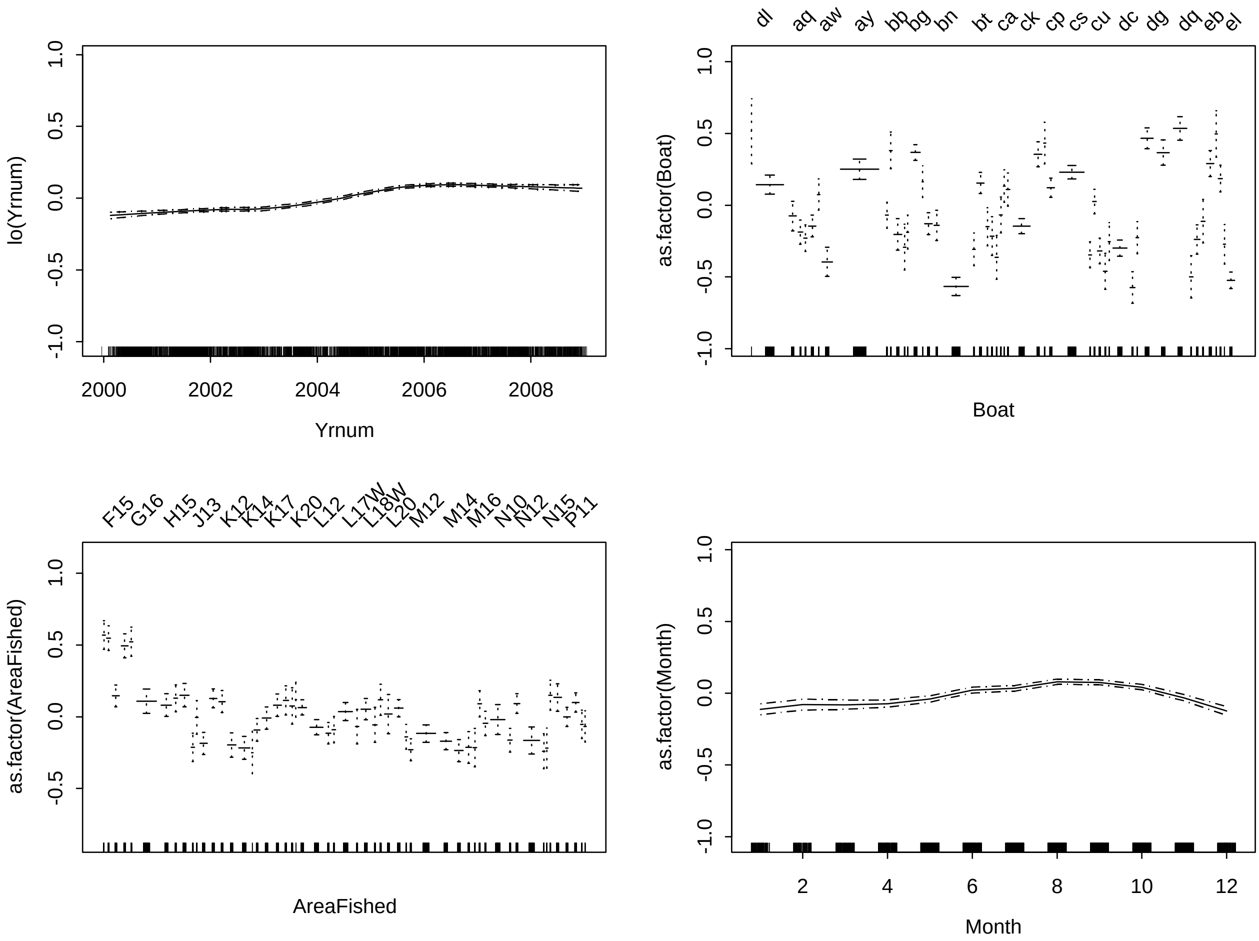


Figure 2.9. Brown crab diagnostic GAM plots of the fitted curve (continuous line) and factors included in the minimal model. Data are: Yrnum - monthly time series from January 2000 to December 2008; Boat - fishing vessel; Area - SSMO statistical square; Month - month of fishing regardless of year, months are represented by numbers commencing with 1 = January. The rug plot at the base of each figure indicates the location of each of the data points fitted for the variable, and the broken lines indicate standard errors.

2.2.2.3 Ireland

Stock structure of crab is determined by migration of adult crab and dispersal of larvae. Tag return data off the Irish coast indicate that crab undertake extensive migrations (Figure 2.10). On the basis of tag return data and the distribution of fishing and landings four stocks may exist. The Malin Shelf stock is the largest in extent. Tag return data shows extensive return migrations from north Donegal to Mayo and between inshore coastal waters northwest to the 200m depth contour. These data also show some connection between west of Mayo and the Clare coast. The northern boundary is unknown but fishing activity and landings are low in offshore waters between 56-57°N.

The south west stock occurs mainly in inshore waters out to the 12nm limit. Surveys in 2006/2007 between 6–20nm offshore did not find any significant stocks in offshore waters to the south west. Small scale inshore-offshore migrations occur in this area on a seasonal basis. Boundaries between the south west coast stock and the Celtic Sea stock to the east are unknown. Larval dispersal is probably in the south west direction along the south Irish coast. There is no significant fishery in the southern Irish Sea. There is a limited inshore/offshore migration and a westward migration of female crab from the Wexford coast. Although migration from the Irish south coast may extend as far south as the Scilly Isles, fishing effort and probably crab abundance in offshore waters in the Celtic Sea is low.

Landings in the western Irish Sea have increased recently especially into ports in Northern Ireland. The North West Irish Sea is a retention area which may retain crab larvae spawned along the north east coast. However, there are no data on the migration of adult crabs in the area.

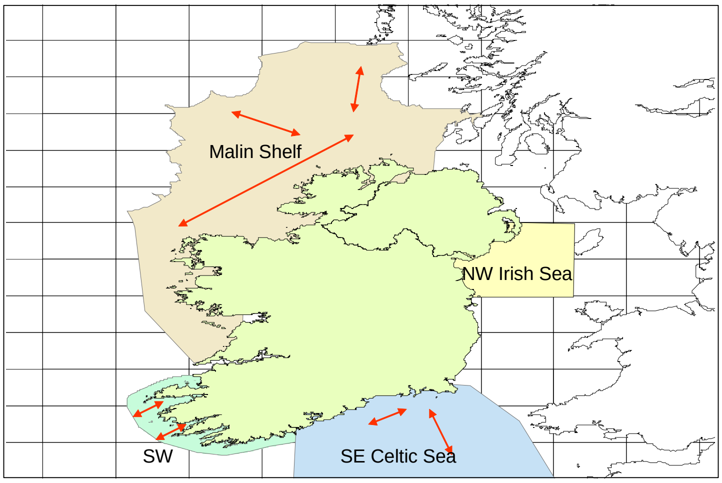


Figure 2.10. Management units for edible crab in waters around Ireland. Arrows indicate the general scale and direction of migration of adult crab where known.

Irish vessels fish for crab in ICES Area IV, VI and VII. The majority of landings originate from Sub-Area VIa south of 56°N (Figure 2.11) although the proportion of annual landings originating from VIa declined from 90% in 2004 to 60% in 2007. There was no change in the spatial pattern of landings within VIa during the period 2004–2008 except for an increase in landings north of 58°N (north of Scotland) in 2006 and 2008 in particular. Landings are relatively small in Area VII by comparison. Area VIIb and VIIj accounted for approximately 20% of national landings in 2007 (Figure 2.12). Landings from Area IVb increased in 2007 and 2008 in particular and accounted for 16–17% of total landings.

Catch rate indicators

Data on landings per unit effort (LPUE) are sourced from private diaries of the offshore vivier vessels. This series extends from 1990, when the vivier fleet was first established, to 2008. Data for the <13m fleet originates from private diaries and reference fleet programmes. Data series for the <13m fleet for the period 2000–2008 exist for the south west (VIIj) and northwest (VIa).

The offshore data series is a significant data set capturing up to 60% of all fishing activity by the Irish offshore fleet in any year and typically represents the landings from up to 1 million pot hauls per year. The diary records are aggregated to the landings per day for gear with similar soak times for the average fishing position on that day. As the majority of fishing activity and its distribution is captured in the index in most years the data are thought to be an unbiased indicator of LPUE. The LPUE is reported in nominal values. Previous standardisation for changes in catchability using GLM did not significantly affect the nominal index.

The main weakness in the data set is the lack of information on the proportion of the catch that is not retained on board but returned alive to the sea because of size limits or poor quality. Grading practice varies between vessels and may also be variable over time.

Area VIa and IVa

Vivier fleet

The geographic distribution of activity covered by the LPUE data reflects the main distribution of fishing activity by the fleet as indicated by the landings data (Figure 2.11).

Monthly variability in LPUE was high up to 2004 with peak LPUE generally occurring in Autumn and Winter during this period. This pattern changed somewhat during 1995–2000. Seasonal variability and peaks in LPUE were lower later in the series (Figure 2.13).

The annual index declined from 2.6–2.8kgs per pot haul in 1990–1992 to 1.8 kgs per pot haul by 1994 (Figure 2.14, Table 2.3). LPUE was stable between 1.6–1.8 kgs during 1994–2000 but declined in 2001. The index was stable between 1.4–1.5 kgs from 2001 to 2004, increased to 1.7 in 2005 but fell to a record low of 1.25 in 2006. No data are available south of 58°N for 2007–2008.

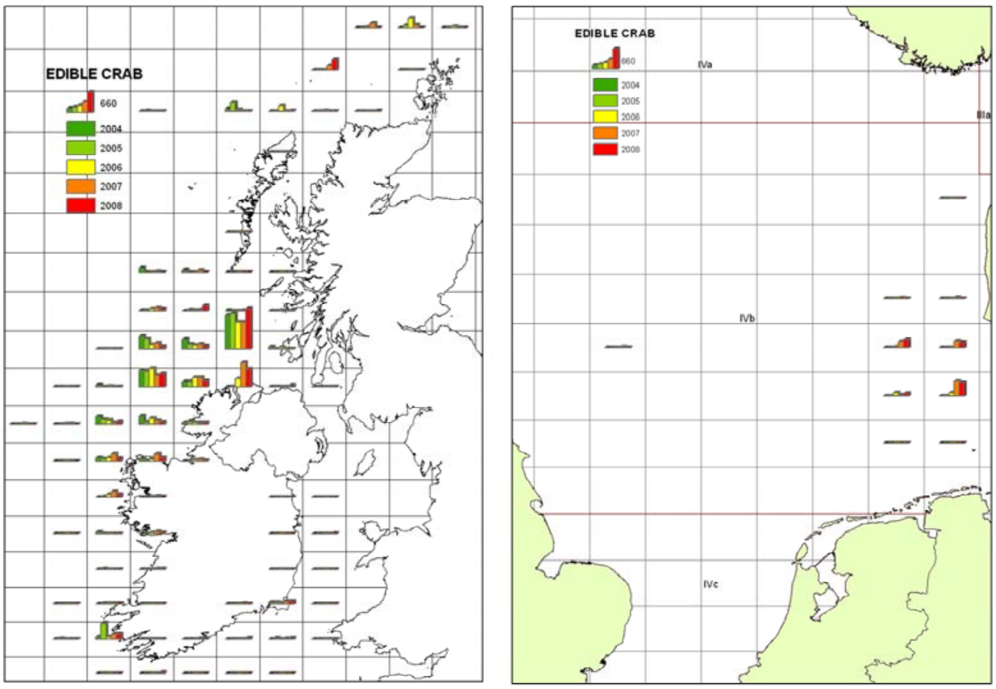


Figure 2.11. Origin of landings into Irish ports of brown crab, by ICES rectangles, by vessels of all jurisdictions, from 2004–2008.

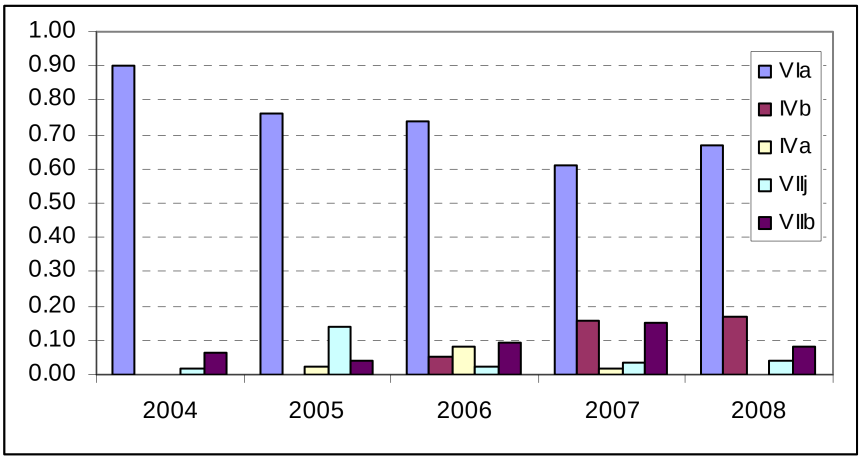
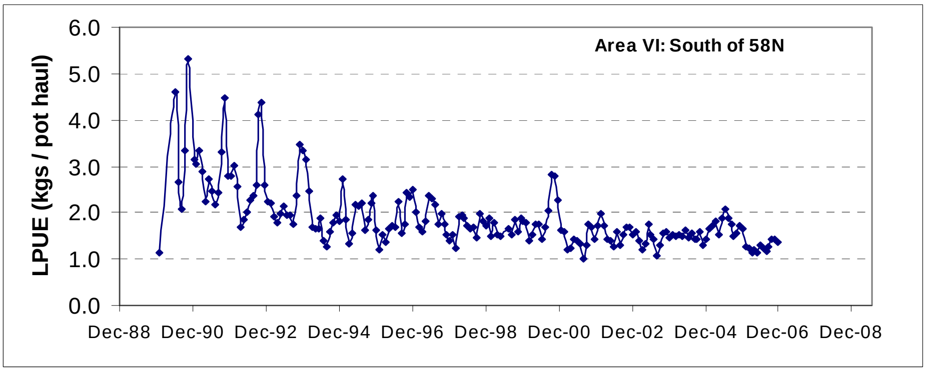


Figure 2.12. Annual proportion of brown crab landed from each ICES sub-division by vessels all jurisdictions landing into Irish ports.



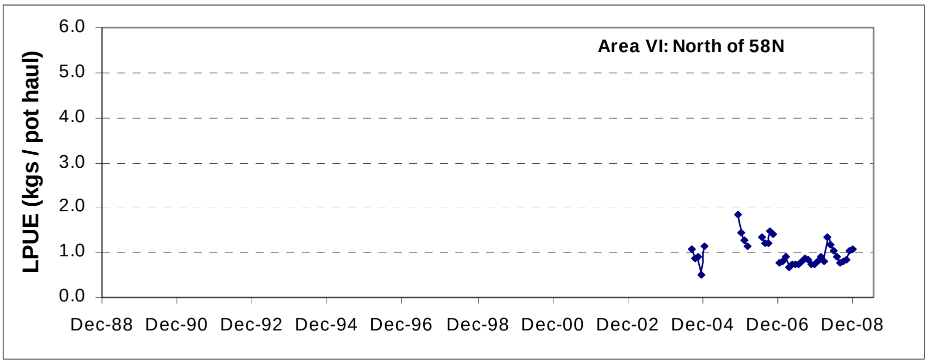


Figure 2.13. Monthly LPUE (kgs per pot haul) for the Irish vivier reference fleet north and south of 58ºN in Area VI.

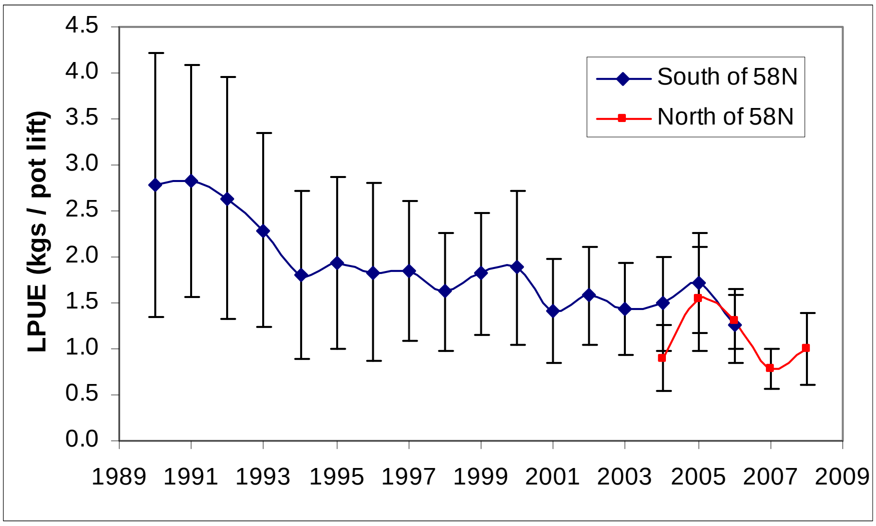


Figure 2.14. Annual average (±s.d.) LPUE in the Irish vivier reference fleet in Areas VI north and south of 58oN.

Table 2.3. Annual average (±s.d.) LPUE and associated effort (pot hauls) in the Irish vivier crab reference fleet. N = fishing events standardised to gear with common soak times within days.

	South of 58N				North of 58N			
Year	N	Mean	S.d.	Pot hauls (reference fleet)	N	Mean	S.d.	Pot hauls (reference fleet)
1990	55	2.79	1.43	28000				
1991	348	2.82	1.26	155700				
1992	636	2.64	1.31	214500				
1993	1181	2.29	1.06	471614				
1994	1338	1.81	0.92	664520				
1995	1432	1.93	0.94	666288				
1996	5012	1.83	0.97	586568				
1997	1214	1.85	0.75	665240				
1998	1415	1.63	0.64	812025				
1999	1120	1.82	0.67	629050				
2000	1275	1.88	0.84	703470				
2001	1213	1.41	0.57	928375				
2002	1432	1.58	0.54	1213350				
2003	1100	1.43	0.51	837925				
2004	1353	1.49	0.52	1207850	177	0.90	0.36	95500
2005	1344	1.71	0.55	937609	71	1.54	0.56	38750
2006	1369	1.25	0.40	1135200	310	1.30	0.29	259350
2007					498	0.78	0.22	237576
2008					346	1.01	0.39	210822

<13m fleet

The geographic distribution of fishing activity represented in the catch and effort reference fleet data for the <13m fleet is mainly north Donegal from Malin Head to Tory Island in the west and north to approximately 20 miles offshore. The 2008 data also include information for the north Mayo fishery west of Donegal Bay.

Seasonal peaks in LPUE occurred mainly in October of each year with secondary peaks occurring in July in some years. Seasonal minimum LPUE occurred in the March–May period (Figure 2.15).

Annual LPUE was stable during the period 1993–2007 fluctuating around a long term average of 1.47 kgs per pot haul. In 2008 the combined Mayo and Donegal fishery average LPUE was 0.84. The average in Donegal and Mayo was 0.72±0.55 and 1.31±1.39 kgs per pot haul respectively (Figure 2.16).

Monthly LPUE was positively correlated with monthly DPUE and both indices showed the same seasonal pattern; that is high rates of discarding occurred when landings per unit effort are also high (Figure 2.15). The seasonality in LPUE is, therefore, unlikely to be due to changes in discard rates.

Annual LPUE appears to be stable between 1.0–1.5 kgs per pot (Figure 2.16, Table 2.4). Monthly DPUE peaked in August and September and was lowest in April and May. On average approximately 30% of the catch was discarded. This varied seasonally from 20–40% but occasionally up to 60% of the catch was discarded (Figure 2.17).

Area VIIj (south west Ireland)

<13m fleet

The geographic distribution of the catch rate data extends along the south west coast of Ireland. Various surveys were completed during 1999–2007. Survey data are reported separately to data obtained under normal commercial conditions. The resolution of the data is a mixture of individual fishing events (individual strings of pots) and fishing events aggregated to boat day level.

Catch rate data from the private diaries of reference fleets, operating under normal commercial operations, corresponds well with survey data which generally had observer coverage (Figure 2.18, Table 2.5). Peak LPUE occurred in the period August–October. LPUE was lowest in April and May. LPUE declined during the period 1999–2008. Annual average LPUE declined from 2.29kgs per pot in 2000 to 1.57kgs per pot in 2004 and was stable from 2004–2007. The average for 2008 was 0.23kgs per pot (Figure 2.19). Discard rates were practically zero which is in marked contrast to the north west fishery. The catch from this fishery is processed rather than exported live which is the main market for the North West fishery.

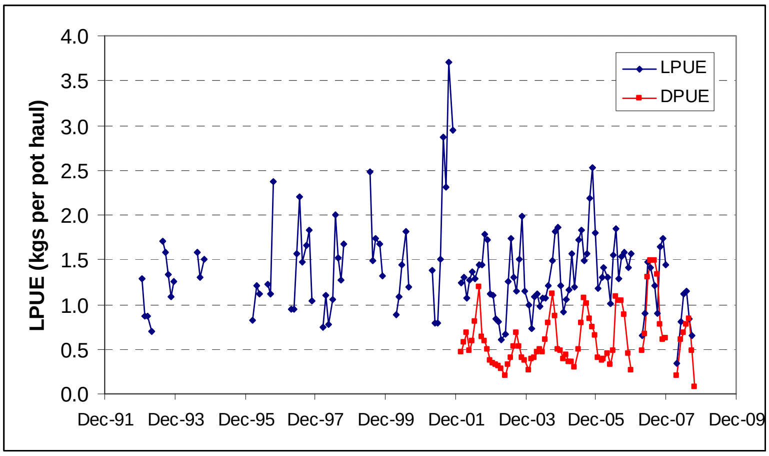


Figure 2.15. Monthly LPUE and DPUE in the <13m crab fishery north of Donegal and for 2008 Mayo and Donegal.

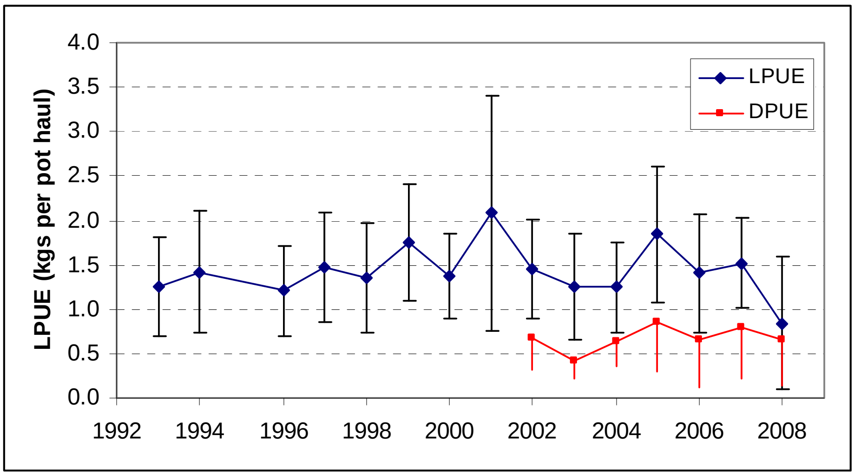


Figure 2.16. Annual LPUE (±s.d.) in the <13m crab fishery north of Donegal and for 2008 Mayo and Donegal.

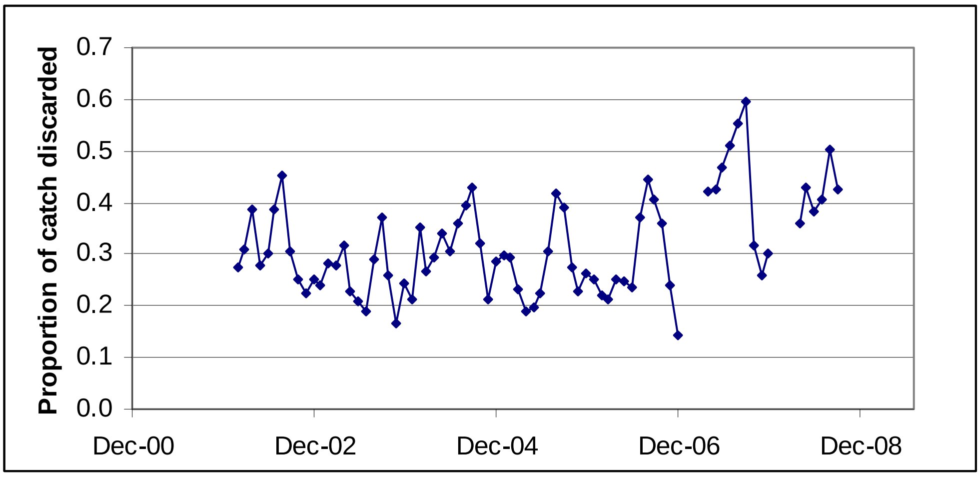


Figure 2.17. Monthly proportion of the crab catch discarded by the <13m fleet in Area VIa 2001–2008.

Table 2.4. Annual LPUE and DPUE (±s.d.) and reference fleet effort in the <13m crab fishery north of Donegal between 1993 and 2007 and off Mayo and Donegal in 2008. N = number of vessel days.

	LPUE				DPUE			
Year	**N**	**Mean**	**S.d.**	**Pot hauls**	**N**	**Mean**	**S.d.**	**Pot hauls**
1993	87	1.25	0.56	56895				
1994	29	1.42	0.68	31725				
1996	85	1.21	0.51	43650				
1997	91	1.47	0.61	51000				
1998	84	1.35	0.61	40650				
1999	99	1.75	0.65	46050				
2000	62	1.37	0.48	32550				
2001	131	2.08	1.33	45550				
2002	448	1.45	0.56	232650	182	0.67	0.35	69905
2003	1274	1.26	0.60	317797	128	0.42	0.20	68137
2004	339	1.24	0.51	212510	161	0.64	0.28	104060
2005	1414	1.84	0.77	742152	1143	0.85	0.56	623175
2006	872	1.40	0.67	481902	604	0.66	0.55	364256
2007	373	1.52	0.51	207300	373	0.80	0.59	207300
2008	147	0.84	0.74	79505	127	0.66	0.51	44590

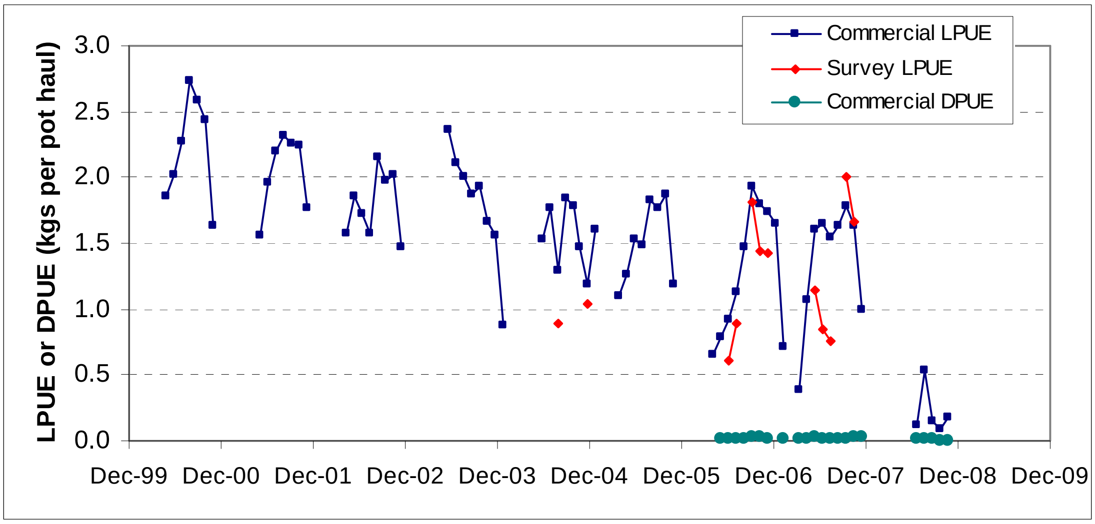


Figure 2.18. Monthly LPUE and DPUE of crab in the <13m reference fleet off the south west coast of Ireland between 2000–2008.

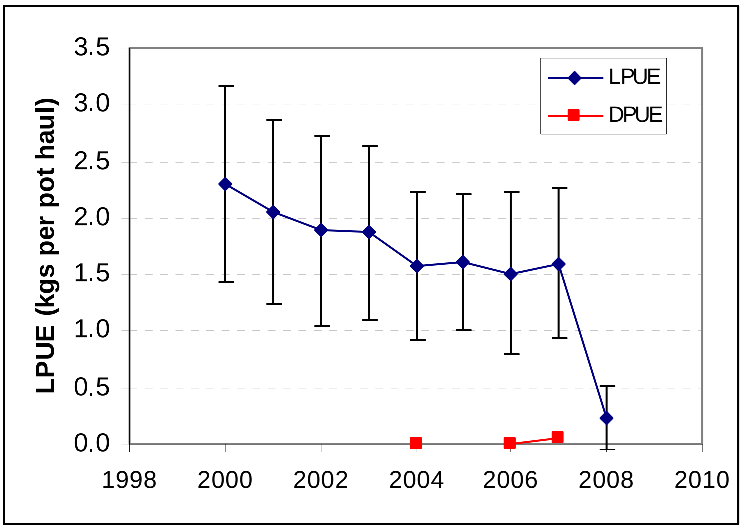


Figure 2.19. Annual average (±s.d.) crab LPUE and DPUE in the <13m south west crab reference fleet 2000–2008.

Table 2.5. Annual average (±s.d.) crab LPUE and DPUE in the <13m south west crab reference fleet 2000-2008. N=number of fishing events reported. Pots = sum of the effort represented by the data.

Year	Pots	LPUE			DPUE		
		N	Mean	S.d.	N	Mean	S.d.
2000	54740	782	2.29	0.87	0		
2001	56580	943	2.05	0.81	0		
2002	52120	857	1.88	0.84	0		
2003	57360	956	1.87	0.77	0		
2004	54590	881	1.57	0.65	140	0.004	0.002
2005	74220	1237	1.61	0.61	0		
2006	145808	1883	1.51	0.72	32	0.004	0.003
2007	265851	3890	1.60	0.67	96	0.051	0.027
2008	25780	48	0.23	0.28	0		

2.2.2.4 France

Potters represent 75% of the landings in the edible crab fishery in France, with netters and trawlers catching the remaining 25%. Landings information is well known for several fleets when the edible crab is one of the targeted species, and for the other fleets an estimation of the landings is performed from the valuable data. Today, only the offshore potters target edible crab all the year. These 20 metre vessels undertake one-week trips during low tide from April to December. In 2008, this fleet represents 41% of the French production.

Landings

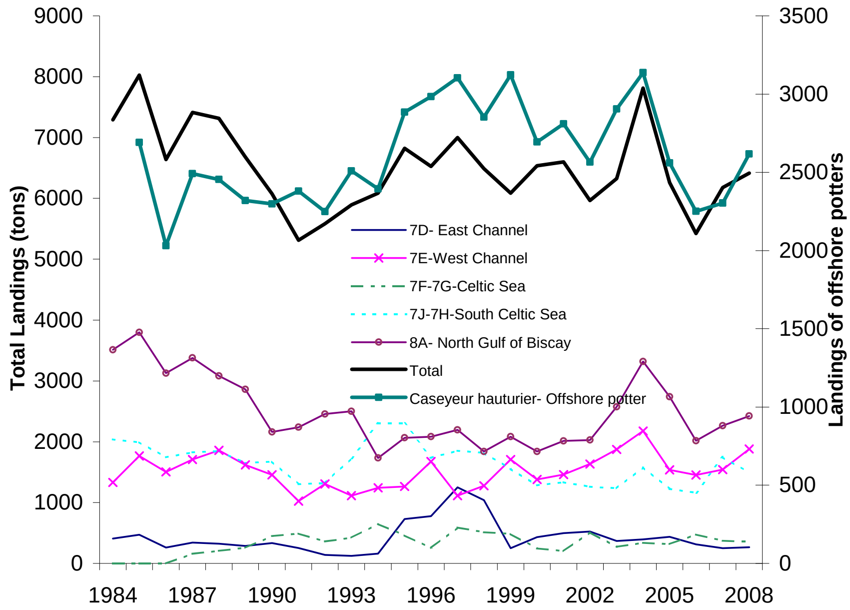


Figure 2.20. Landings of edible crabs by French vessels.

The French production in 2008 is around 6500 tonnes (Figure 2.20). This value follows the global trend of the last 20 years. In the short term there has been an increase in production since 2006. This increase is observed in the 3 main fishing areas located in the 7E, 7H, 8A ICES divisions. This situation is well characterized by the offshore potter fleet where the production has increased by 17% despite a reduction from 13 vessels in 2006 to only 11 in 2008. Without the reduction of this fleet we can suppose that the 2008 landings would have reached 7000 tonnes.

Abundance Index of Crab

As in the previous year, the data from the offshore potter fleet are used to estimate an abundance index. The quality and the long-term series of these data are good elements to develop a robust index. The abundance index is estimated by fitting a GLM model to the data. The model parameters are year, month and area. This type of model permits the estimation of an index where the spatial, seasonal and annual variability are introduced. Four areas are considered, we include in the same area the Western Channel and the south of the Celtic Sea. In the data table, each line represents by boat, trip, year, month and area, the catch and the number of pots used. The fishing time by pot is always around 24 hours.

As with the previous analysis, all the variables are conserved in the retained GLM model and the cross effect between year and area. This cross effect characterises a different annual evolution of the index abundance in the 4 areas (Figure 2.21). The data selected for this result exclude the months from January to May without modify the general trend in the areas. During this period, the activity of the vessel is very irregular with very low CPUE levels.

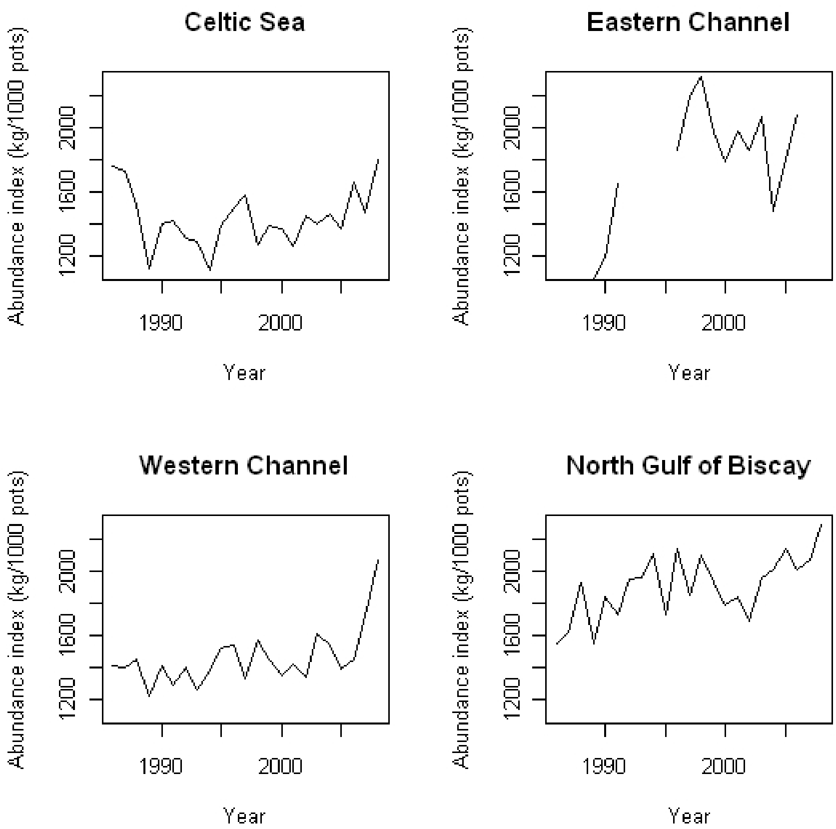


Figure 2.21. Evolution of the abundance index in 4 different areas.

The increase of the index abundance observed in 2007 in the Western Channel is amplified in 2008 (Figure 2.22). Successively, 2007 and 2008 are the years with the highest recorded index. For the Celtic Sea and North Gulf of Biscay, there was a decrease in the abundance index in 2007, followed by a significant increase in 2008. Even if this index is dependent upon catchability, on a long-term series we have robust information on the stock status. In 2008, the indices from the different areas suggest good status of the stocks. However these are the aggregated trends for these four regions, and we have observed a decrease of the index in 2 or 3 coastal areas. Currently we don't have any information to why 2008 had such a high abundance index particularly in the Western Channel. The future use of more precise spatial data could provide the key to understanding these fluctuations in abundance.

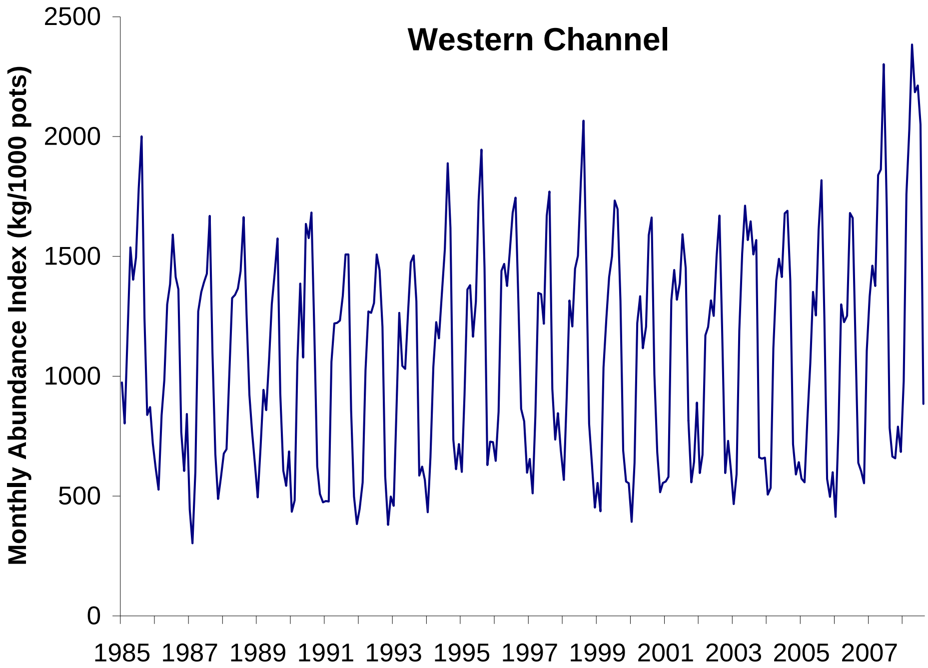


Figure 2.22. Time series of the monthly abundance index for the Western Channel area.

2.2.2.5 Norway

The Norwegian fishery for Brown crab (*Cancer pagurus*) was expected to increase even further from the peak level in 2007. However, the international market situation led to a reduction in catches of near 40% in 2008 (Table 2.6). The largest reduction came in the northern areas, where the crab fishery has expanded in recent years. The fishery for brown crab in Norway is an inshore coastal fishery using traps. The peak season in the crab fishery is from August to November. Vessels 10–15 m in length fish with traps and deliver the live catch at a few processing plants.

In 2001 a programme for mapping biological data of the brown crab resource was initiated. The logbooks provide data on catch-rates (Table 2.7), sex, size and discards for calculation of annual indices in selected geographic regions.

In area 05 (Vesterålen), only a few fishers are working and only one and the same fisher provided the data in 2008 as in the years before. Due to a newly started fishery it may be expected that the catch-rates would increase with time. The catch rates in this area now seem to be established at the same level as in the area to the south. In area 06 (Helgeland and N-Trøndelag) the catch rates are still high and no trend is observed. In area 07 (S-Trøndelag, Møre and Romsdal) the catch rates are stable during the period, although a small increase may be seen in the later years. In 2005 and 2006 there were no fishers reporting from the south-west (area 08). In the later years there were four fishers reporting, although not from the same localities as in the earlier years. There seems to have been an increase in the availability of larger crabs in the area.

The catch-rates in 2008 vary between the areas, 3.66–2.74kg/trap for landed crab and 2.20–0.81kg/trap for discards. The catch rate of landed crab seems to be of a comparable size in all the areas. The catch rates of discards still differ in the areas, being lower in the northernmost area.

As the catches have been increasing, and now decreasing, there still seem to be no trends in the CPUE indicating any reduction in the available stock of brown crab in the Norwegian waters. Investigations on yield per biomass seem to indicate a very high fishing pressure on the stock. This was also found in earlier investigations based on tagging.

The minimum legal landing size is set to 11cm carapace width (CW) in the southern areas and to 13 cm in the northern areas. This seems to correspond to somewhat less than 50% of maximum catch rate in the pots, especially in the northern areas, and the question may be raised if there would be a gain to increase the minimum legal landing size by one cm, to 12 cm and 14 cm. This would imply a loss of catch in weight of 10 to 15%. With the present market situation, the Norwegian sales organisations are also interested in looking into the benefits of an increased landing size. From the point of view of giving management advice, this situation may give room for setting a minimum legal size based on securing the spawning potential of the stock, provided sufficient effort is put into scientific work.

Investigation of the size distributions reveals no information as to changes in the size distribution due to increased exploitation. Based on this information it seems as if the development in the fishery is based mainly on exploiting new areas and the market situation, however, the landings may also vary somewhat due to variation in stock density in fully exploited areas.

Table 2.6. Norwegian landings (tonnes) of brown crab (*Cancer pagurus*) from 1999 to 2008 reported to the Norwegian Directorate of Fisheries. The areas are the official statistical fishing areas.

Area	Name	Geograph.	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
05	Vesterålen	67°-70° W11°	0	0	1	1	17	2	5	1	2	2
00	Lofoten	67°-68.5° E11°	1	1	2	2	28	54	298	335	510	402
06	Helgeland, N-Trøndelag	64°-67°	598	718	684	800	1589	2012	2392	2768	4172	1999
07	S-Trøndelag, Møre and Romsdal	62°-64°	1440	1499	2115	2676	2247	1994	1858	2116	2610	2051
28	Mid-Norway	60°-62°	257	206	241	366	532	503	486	332	461	172
08	SW-Norway	57°-60° W7°	540	465	430	496	527	676	625	637	706	650
09	Skagerak	57°-60° E7°	1	1	2	4	4	5	7			
Tot			**2836**	**2890**	**3476**	**4344**	**4944**	**5248**	**5671**	**6189**	**8461**	**5276**

Table 2.7. Mean catch rates (kg/trap) in the standardised traps in the Norwegian fishery for brown crab during the whole fishing season (10 weeks of sampling). Landings per unit effort (LPUE) are crabs larger than 13cm carapace with and discard per unit effort (DPUE) are smaller crabs. Data revised in 2009.

	Vesterålen (Area 05)		Helgeland and N-Trøndelag (area 06)		S-Trøndelag, Møre and Romsdal (area 07)		South-west Norway (Area 08)	
Year	LPUE	DPUE	LPUE	DPUE	LPUE	DPUE	LPUE	DPUE
2001	1.13	0.90	2.84	0.80	1.78	1.14		
2002	0.96	0.71	2.95	1.25	2.13	1.19	1.03	1.73
2003	1.09	0.51	2.40	1.01	2.07	1.27	1.08	1.78
2004	2.12	0.68	2.94	0.82	2.06	1.25	1.32	3.03
2005	1.78	0.62	2.65	1.11	2.01	0.70		
2006	2.68	0.54	2.78	1.36	2.28	1.30		
2007	4.46	1.11	3.36	1.09	2.87	0.87	1.86	2.86
2008	3.03	0.81	3.00	1.24	2.74	1.77	3.66	2.20

2.2.2.6 Sweden

No essential change in landings has occurred over the past years in Sweden (Figure 2.23). The total landings reported from all gears in 2008 was 146 tonnes. Half of the landings is taken in Kattegat (71 tonnes) and the other half in Skagerrak (75 tonnes). Landing is recorded in 20 gear types but of these the crab and lobster pots, and the crab fyke net and gill-net are the most important (Table 2.8). The landings in *Nephrops* creels may have increased over the last few years (7 tonnes in 2008, 4.5 tonnes in 2006), which may be due to an increase in the edible crab distribution, spreading towards deeper *Nephrops* grounds.

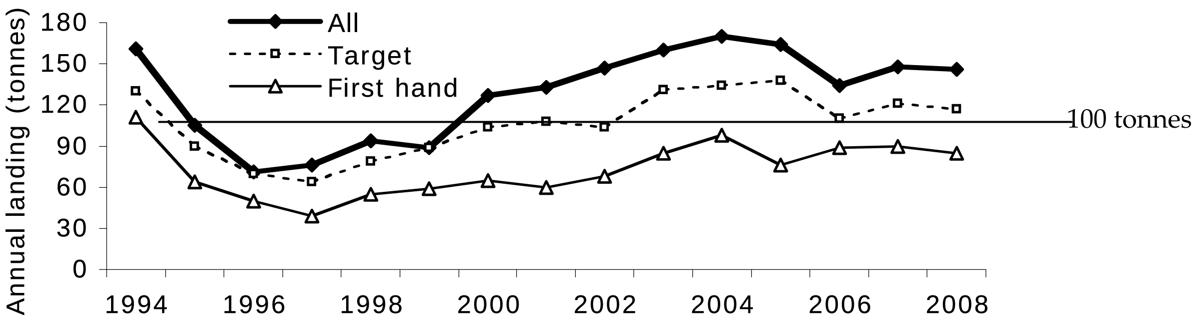


Figure 2.23. Official landings based on log-book data from fishermen (diamonds & boxes) versus reports from first-hand dealers (triangles).

Table 2.8. Edible crab landings in 2008. Log book data. Swedish Board of Fisheries.

Landing (tonnes)		**SUBDIV**		
Gear code	**Gear**	**Skagerrak**	**Kattegat**	**Total sum**
823	Crab pot	41	38	78
821	Lobster pot	15	10	25
702	Gillnets	5	4	10
713	Gillnet, crab	1	8	9
829	Norw lob creel	7	0	7
826	Fykenet, crab	3	2	4
711	Gillnet, flounder	1	3	4
725	Gillnet, turbot	1	3	4
319	Bottom Otter trwl, cod	1	2	2
310		0	1	1
822		0	1	1
716	Gillnet Set, dogfish	0	0	0
714	Gillnet, cod	0	0	0
833	Fykenet, eel	0	0	0
717	Gillnet Set, sole	0	0	0
727		0	0	0
306	Btrawl, Norw lob, grid&square	0	0	0
824	Eel creel	0	0	0
825	Trap	0	0	0
998		0	0	0
Total sum		75	71	146

For vessels < 10 m the fishing activity is reported once a month. But each sheet includes gear type (code based) and number of gears (or total length of net) x number of days fished is given for each gear type (both numbers specified). Mid position of gears is given. Also recorded are fresh/wet landed and discard weight for each species (coded) for each respective gear type.

For vessels larger > 10 m the skipper is required to report the fishing activity within 48 hours, i.e. on a daily basis. They report species landed and discarded, and the amount of gears used. They also record effort hours, which should be interpreted as the time that the gears had been deployed in the sea.

In 2007 nine fishing vessels over 10 metre captured 27 703 kg using 12704 pot hauls i.e. a rough LPUE estimate is 2.18 kg/pot. Using this landing rate, pot hauls for vessels < 10 m are estimated at 24432 hauls (53 263 – 27703/ 2.18). This gives a total annual effort of approximately 37 000 pot hauls for the Swedish commercial fishery.

2.2.2.7 Other brown crab fisheries

There are a number of other countries and areas in which significant brown crab fisheries occur, and for which little or no information was provided to the WG. For example, the Channel Islands (Jersey and Guernsey), Belgium and Denmark all have *Cancer pagurus* fisheries, and the WG agreed that in future we should attempt to compile fisheries statistics for all countries irrespective of whether these countries were represented at the WG.

2.2.3 Velvet crabs (*Necora puber*)

2.2.3.1 Shetland Isles

The velvet crab (*Necora puber*) fishery is rapidly increasing in its importance to Shetland's inshore fleet, and landings have almost tripled since the regulating order was introduced in 2000 (Figure 2.24). In July 2001 the Shetland Shellfish Management Organisation introduced a 70 mm carapace width minimum landing size (the national MLS is 65 mm) and they have also implemented summer closed seasons in July and August on the west coast, and September and October on the east coast. These closed seasons were implemented, in part, to better reflect observed differences in the moult cycle between populations on the west and east coasts. From 2006 to 2008 the summer moult period was reported to be very variable and the closed season did not always match the pattern of moulting (Leslie & Shelmerdine, 2008).

Landings and effort have increased in this fishery since 2004, and substantially in 2008 due to vessels moving from the brown crab fishery due to poor market conditions. This most recent landings increase has been accompanied by a decrease in LPUE (Figure 2.24).

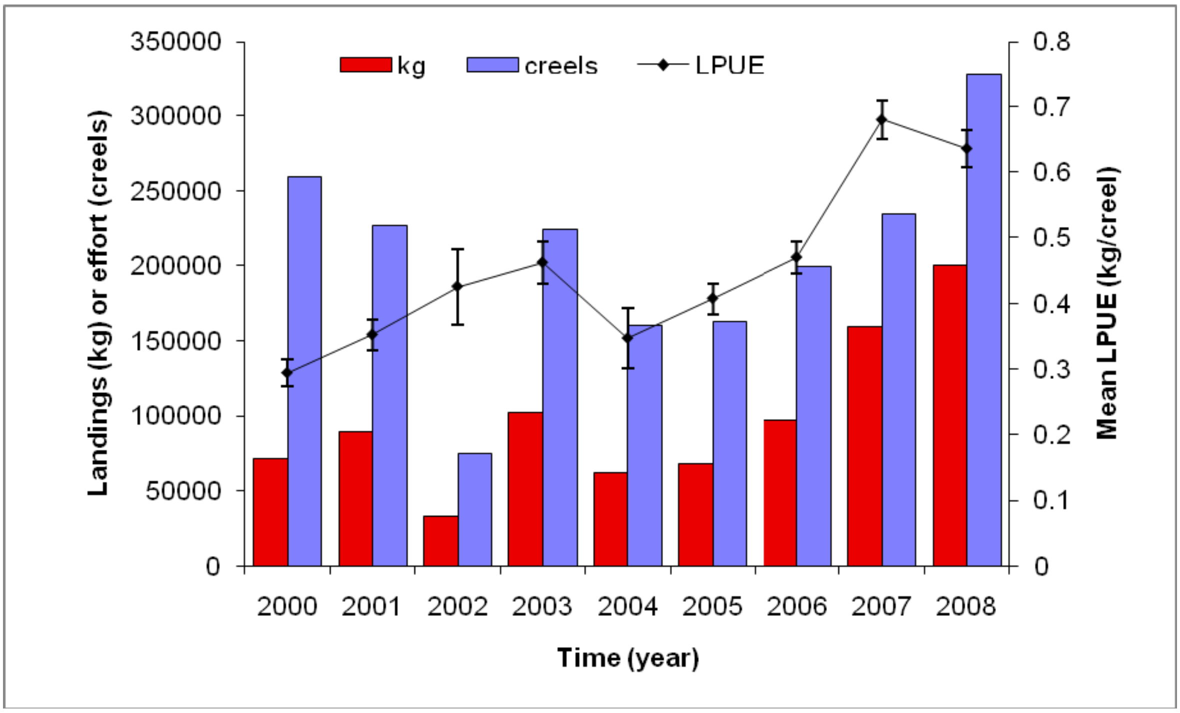


Figure 2.24. Total velvet crab landings (kg), total numbers of creels catching velvet crabs, and the average LPUE obtained from SSMO logbook data with 95% confidence intervals shown.

A generalised additive model was used to further examine trends in LPUE. All four explanatory variables (year, month, vessel, area fished) had a significant effect on the model and were therefore retained in the analysis (Figure 2.25). LPUE has shown an overall increase over the period of data collection with a marked increase between 2005 and 2008. The most recent dip in LPUE values does not appear to have affected the overall trend in LPUE described in the GAM analysis as yet. Seasonal effects indicate that LPUE decreases from January to April and then shows a period of increase until September. Following this, LPUE levels off until December (note that the data include landings in 2000 and 2001, before the closed period during the summer months was implemented in this fishery). Vessel and area effects are similar to those reported in the previous assessment (Leslie *et al.*, 2008). Vessel effects were very variable with large between vessel differences - however details of these differences have not been examined further.

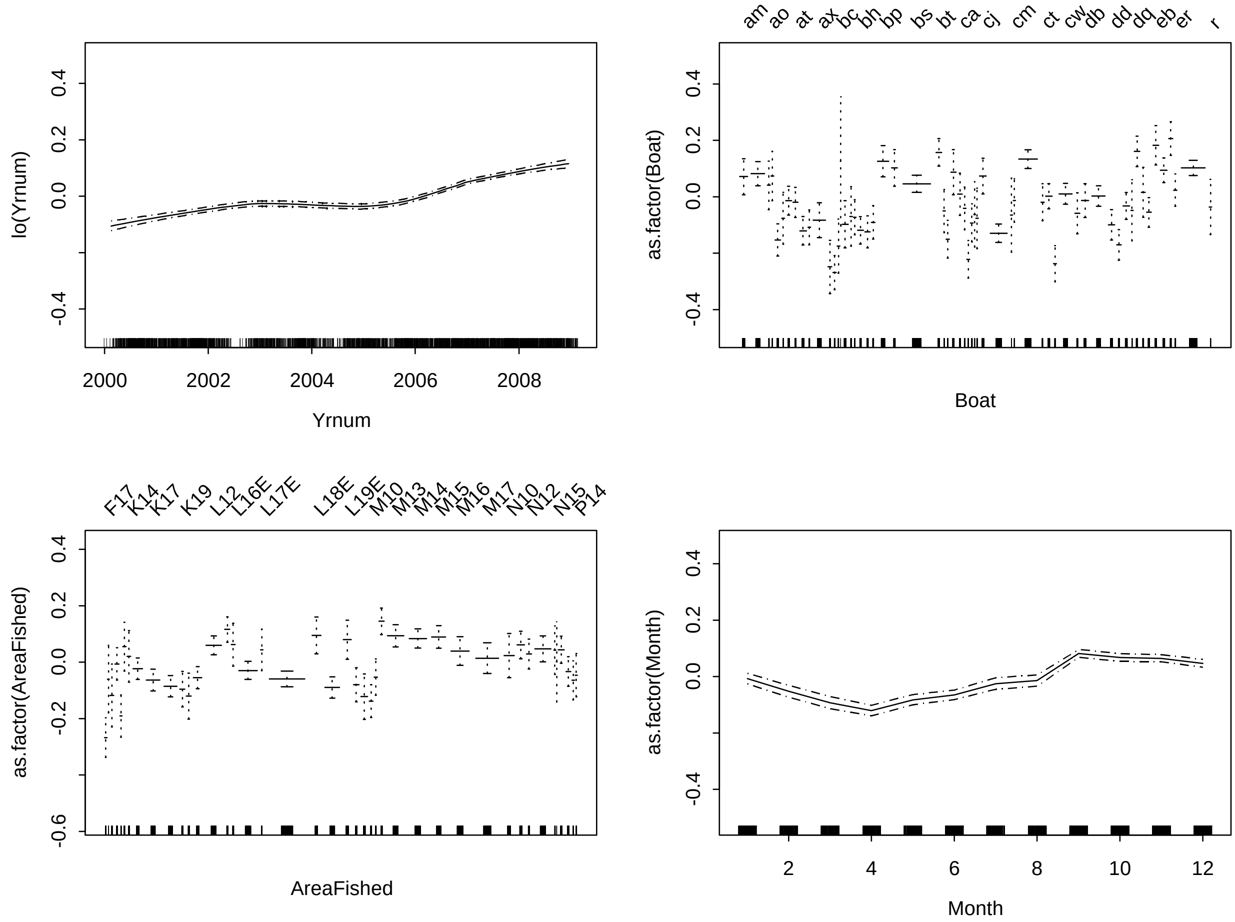


Figure 2.25. Velvet crab diagnostic GAM plots of the fitted curve (continuous line) and factors included in the minimal model. Data are: Yrnum. – a monthly time series from January 2000 to December 2008; Month - month of fishing regardless of year, months are represented by numbers commencing with 1 = January; Area Fished - SSMO statistical rectangle; Boat - fishing vessel. The rug plot at the base of each figure indicates the location of each of the data points fitted for the variable, and the broken lines indicate standard errors.

2.2.4 Spider crab (*Maja brachydactyla*)

2.2.4.1 Ireland

The majority of the data reported here has been collected from the spider crab fishery in Brandon and Tralee Bays in 2009. This area is responsible for the majority of the national landings of spider crab.

Catch Rate Indicators

Catch per unit effort data was obtained from a voluntary reference fleet programme from March until September 2009. Observer data were recorded during the 2009 fishing season from the beginning of April to the first week of June. Catch, discards and landings per unit effort data were recorded, along with biological measurements of the catch. A total of 2504 spider crab were sampled over a ten week period.

The reference fleet in 2009 was a significant proportion of the total fleet and is regarded as an accurate representation of catch and effort for the Tralee and Brandon Bay fishery. The observer data on catch rate is less precise and potentially biased due to variable catch rates between vessels and limited coverage of fishing trips.

Monthly landings per unit effort (LPUE) recorded from the reference fleet programme (March-September 2009) peaked at approximately 92kgs per 100 pots in March. Monthly discard rates (DPUE) during the same time period peaked at approximately 319kgs per 100 pots in June, increasing from 90 in March. Mean catch per unit effort (CPUE) data also peaked in June at approximately 382kgs per 100 pots (Figure 2.26).

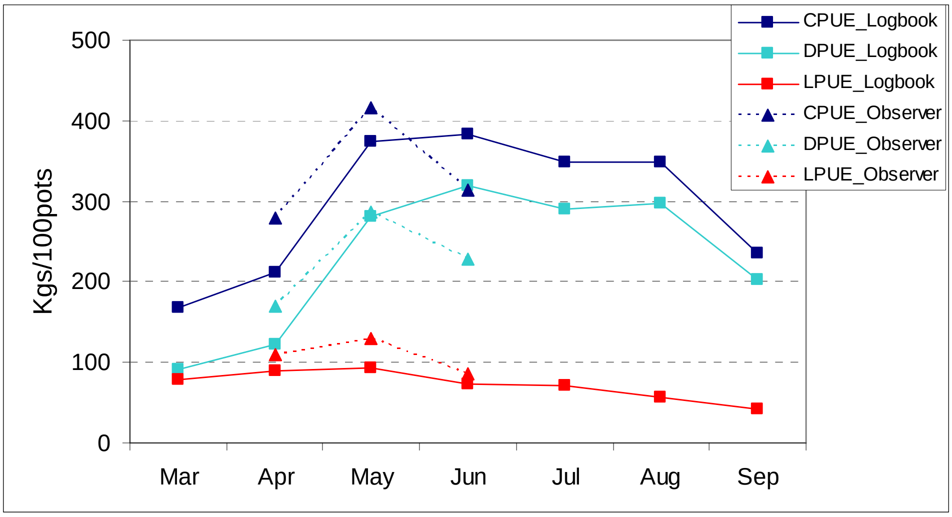


Figure 2.26. Catch and effort indicators for the spider crab reference fleet and observer programme in Brandon and Tralee Bays in 2009.

DPUE increased from March to May, was stable between May and August and declined in September. LPUE increased slightly from March to May and then declined.

The observer data showed a peak in all three catch indicators in May (LPUE at 129kgs per 100 pots; DPUE at 286kgs per 100 pots and CPUE at 415kgs per 100 pots). Peaks for CPUE and LPUE were slightly higher than the reference fleet data for April and May. However, in June the observer estimates, of both catch and discards per unit effort, were lower, although only one sampling trip was undertaken at the beginning of June.

Observer data showed that on average >65% of spider crab sampled each month were discarded, because they were undersized or damaged. The rate of male crab discarding increased from 62% in April to 69% in June, whereas female discards declined from 71% in April to 55% in June. The reference fleet data indicated that over 50% of the catch was discarded in March and this increased to over 80% in August and September. Approximately 62% of male and 65% of female adult crabs in the catch were below the MLS.

Regression of LPUE on cumulative catch (total = 220 tonnes) suggests a pre-fishery biomass, above the MLS, of 380 tonnes and a season exploitation rate of crabs above the MLS of 57% (Figure 2.27).

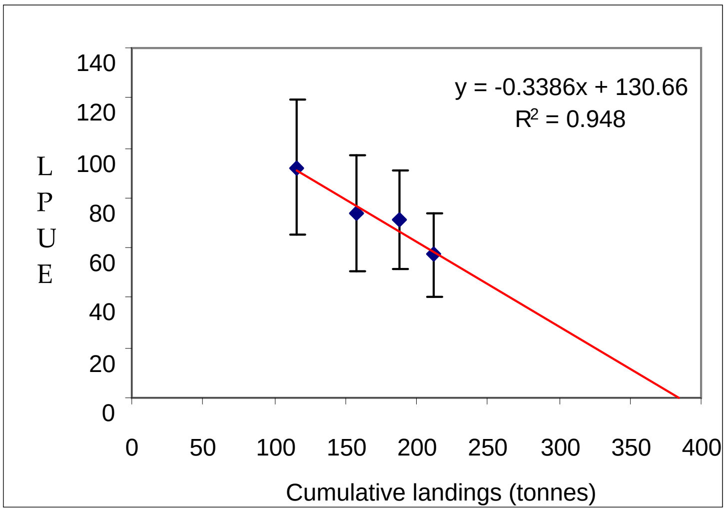


Figure 2.27. Regression of LPUE (kgs/100 pots) on cumulative landings of spider crab during 2009.

Size composition, maturity and fishing mortality

In total, 894 female spider crab were sampled during 2009 of which 98% were mature with only 2% of the females caught having 'flat' abdomens and therefore classed as immature. The percentage of crabs that were berried increased from 66% in April to 94% in May and to 100% in July (Figure 2.28). The carapace length of egg bearing females ranged from 118 to 127mm.

Female length frequencies, from the 2009 observer data, ranged from 83 to 156mm with a mean length of 125±34.5mm (Figure 2.29). Males were larger than females, ranging from 89 and 178mm (mean length = 131±13.7mm). Males were dominant in the catches from April to the beginning of June.

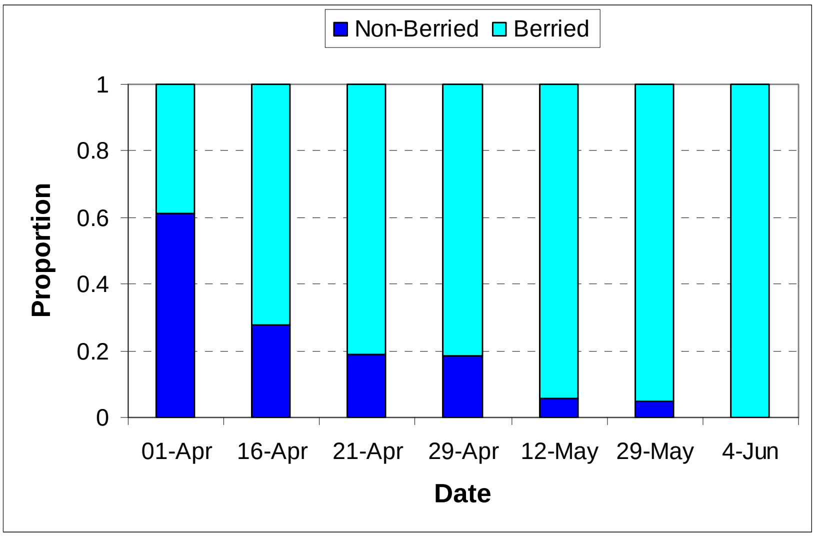


Figure. 2.28. Proportion of berried to non-berried female spider crab in the catch between April and June in the 2009 Tralee and Brandon Bay fishery.

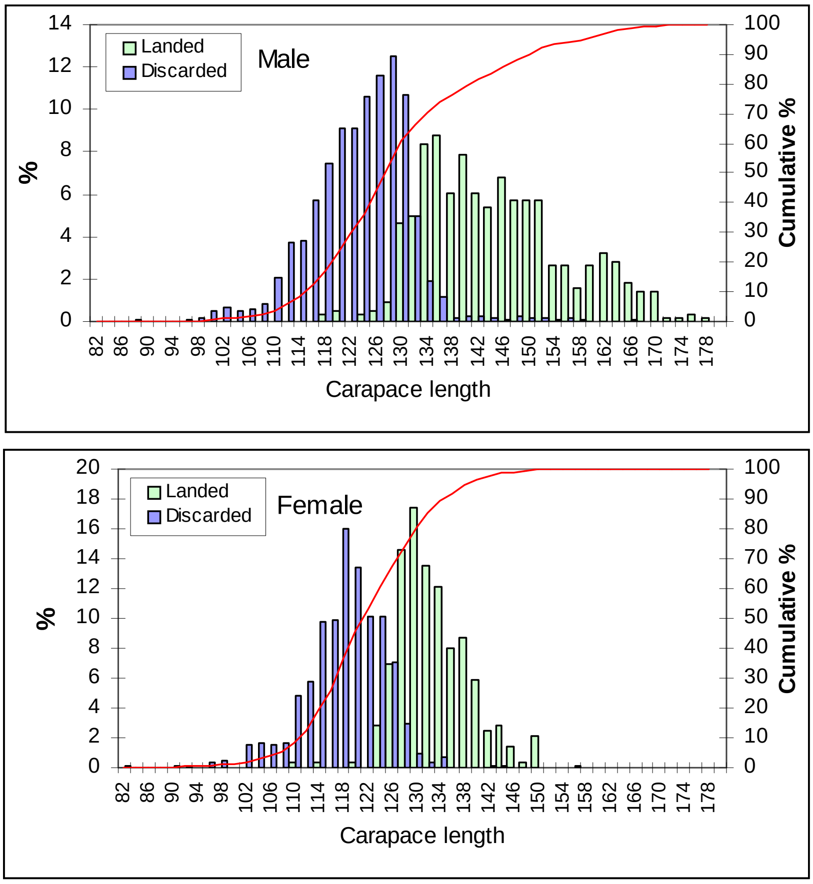


Figure 2.29. Length composition of discarded and landed male and female spider crab and cumulative length distributions of the catch of spider crab in the 2009 Tralee and Brandon Bay fishery.

2.2.5 Red king crab (*Paralithodes camtschaticus*)

2.2.5.1 Norway

From 2007 Norwegian and Russian authorities decided to split the joint management regime on the red king crab in the Barents Sea into separate national regimes. This entails that the crab stock in this area are considered as two separate stocks; one in Norwegian waters and one in Russian waters. The offshore distribution of the crab in the Russian zone probably indicates that the stock here are one unit, while in the Norwegian zone there are several separate stocks limited by several large fjords in the distribution area.

A new management regime was implemented in the Norwegian zone in 2008, which divided the crab distribution in two parts; a commercial area where the crab stock is viewed as a sustainable fishing stock. Outside this area there is an open access fishery without any legislation aimed to limit further spread of the crab.

Catch quotas within the commercial area for 2008 were divided into non-injured male (NIM) crabs (1925 tonnes), injured male (IM) crabs (450 tonnes) and female (F) crabs (235 tonnes). All landed crabs must be larger than a minimum legal size of 137 mm carapace length. At the end of the season 1611 tonnes NIM, 377 tonnes IM and 110 tonnes F were landed. An all too high exploitation rate combined with a reduced fishable stock was probably the reason for landings not reaching the quotas. In all 278 vessels participated in the Norwegian king crab fishery in 2008, the highest number ever in this fishery (Table 2.9).

The king crab stock assessment of the legal male stock in the Norwegian zone has been based on area swept sampling annually (Table 2.9). In 2008, a Bayesian approach stock model was developed for this stock. The stock estimates based on the new model calculations indicate that all previous estimates of the legal male stock are far too high.

Table 2.9. Annual total quota of legal male king crabs, number of vessels, stock estimates, exploitation rate and ex-vessel value, in the Norwegian king crab fishery from 2002–2009.

Year	Total quota (numbers)	Number of vessels	Stock estimates (Males ≥ 137 mm)	Exploitation rate	Value NOK (million)
2002	100 000	127	690 000	14 %	32
2003	200 000	197	1 227 000	16 %	62
2004	280 000	260	1 246 000	22 %	75
2005	280 000	272	750 000	37 %	58
2006	300 000	264	901 000	33 %	49
2007	300 000	221	975 000	31 %	50
2008	679 000	282	795 000	85 %	69
2009	518 000				

Results on growth increment and moulting frequency in male and female red king crab in the Barents Sea were presented showing that growth parameters for both sexes were higher in these areas than in the crab's native areas.

2.2.6 Snow crab (*Chioniecetes opilio*)

2.2.6.1 Canada

The Canadian snow crab fishery is not assessed under the auspices of ICES, but there is much that other crab fisheries can learn from the experience of monitoring, assessment and management of Canadian snow crab fisheries.

Monitoring of biomass and recruitment is undertaken through analysis of commercial LPUE (four separate indices – observer, log book, strap and VMS), an autumn multi-species survey to determine an exploitable biomass index, collaborative trap surveys with observers, and inshore trap surveys including small mesh traps which provide a recruitment index. These data provide an exploitation rate index and pre-recruit fishing mortality index, and the percentage of soft shell animals is also an important index.

The WG agreed that it would be instructive to include trends in fisheries statistics and assessment outputs for Canadian snow crab fisheries in future WG reports.

2.2.6.2 Saint Pierre et Miquelon

The French fishery of snow crab at Saint Pierre et Miquelon started in 1996. The landings increased quickly to reach 600 tonnes in 1999 and this level of landings continued until 2001. Since 2002 the landings have fluctuated between 90 and 190 tonnes. The year 2008 appears to be the second bad year of the fishery with only 123 tonnes of landings. This low value is consequence of a decrease of the fishing effort, less vessels and number of fishing days. At the same time the abundance index of the stock is the highest since 2002. This diagnostic on the stock is confirmed by the Canadian study. In 2008, the fishery was mainly characterized by difficulties to sell their product. There is only one factory which exports the snow crab from Saint Pierre et Miquelon. Moreover, all the recruitment indices are positive and, on a large geographical scale, the stock biomass seems to have increased.

2.2.6.3 Barents Sea

A short description of by-catches of snow crab in the Norwegian and Russian parts of the Barents Sea was presented. This crab was observed in the Barents Sea in 1996 for the first time and Russian scientists are now estimating the adult stock to be several million specimens in the Goose Bank area. A few crabs have been found in the Norwegian Economical zone, in northern parts and along the coast of Finnmark, but the main distribution is in the Russian zone.

2.2.6.4 Greenland

No update was received this year from Greenland.

2.3 ToR c: Collate and evaluate all fisheries data from the various national programmes for the Western Channel and Malin *Cancer pagurus* stocks

In 2008 the WG agreed that it should be collating all fisheries data from national programmes to aim to provide international assessments of fisheries which were exploited by more than one country. The WG decided that two *Cancer pagurus* fisheries, the Western Channel stock exploited by UK, French, Channel Islands and Belgian vessels, and the Malin stock exploited by UK and Irish vessels, should be the initial priorities.

Initial discussions for the Western Channel stock highlighted that UK and French scientists currently identify three potentially separate management units in this geographical area – the Celtic Sea, Western Channel and Biscay - and efforts should be concentrated on where the borders might realistically be placed. There may be issues to be resolved such as vessels whose home ports are in one area, but fish in another area, but the aim was to work intersessionally to produce agreed definitions of these management units.

UK and French scientists would collaborate with representatives from the Channel Islands and Belgium (and potentially Irish scientists for the Celtic Sea) to collate an inventory of vessel numbers fishing in each area, landings and fishing effort by ICES rectangle, LPUE trends, VMS data from the larger crab vessels, individual vessel LPUE data, and time series of size distribution data on a specific spatial scale, and any yield-per-recruit analyses based on these size distribution data. Any other available information from these areas such as recruitment indexes (from whatever source) should also be collated. The WG agree that little progress could be made on an international assessment until such data were available and had been scrutinised by the WG.

For the Malin stock, tagging results showed no movement between the Malin area and other areas, and whilst it was clear that both Irish and southwest Scotland vessels exploited these grounds, there was some uncertainty over the northern extent of the Malin stock. As with the Western Channel stock, an inventory was required, although even at this initial stage it was noted that the lack of fishing effort data for the Scottish fleet would provide uncertainty. As there was no representative from the relevant institute in Ireland available to attend this year's meeting, it was not possible to start the process for the Malin stock.

The WG agreed that the relevant members of the WG would work together intersessionally to progress this ToR.

2.4 ToR d: Review data availability for each species/stock in relation to the requirements of the currently available assessment methods for crabs

2.4.1 Background

Last year the WG reviewed the methods available for assessment of crabs stocks. The WG considered that this year it should scrutinise methodology rather than directly carry out stock assessments and addressed ToR d) by reviewing data available for each of the species and how these contributed to any stock assessments carried out.

Initial discussions considered some methodological aspects generally; clarifying that Canadian survey indices were swept area based and used kriging methodology, as well as incorporating other data. In Norway, a Bayesian framework had been applied to data on crab density and was considered successful. Using a Bayesian Approach permits the inclusion of 'prior information' and 'expert knowledge' and had provided a means of dealing with zero observations. It can also be helpful in providing a background probability against which deterministic assessments can be compared and framed. However it was also noted that the formulation of prior distributions is not a trivial task and care must be exercised in ensuring that priors are genuinely based on knowledge, rather than opinion. Estimates of catchability (q) were crucial to population estimates made from surveys whether towed or static gears were used and estimates/assumptions of q varied widely. The distribution of mature male crabs was more regular than the distribution of juveniles and females and this meant trawl surveys could be reasonably effective. However, in some areas of Norway static gear surveys were required because the topography is too rough to use towed gears. Using assumptions about the catch of a pot, kriging and spline methods can be used to estimate total population.

After initial discussions of the different methodological approaches, the WG reviewed assessment approaches by species and regions.

2.4.2 King crab in Norway

The main method used is a swept area survey using a small trawl similar to a beam trawl, in combination with traps to establish mean crab density along with coefficient of variation (CV) for different size categories of crabs. Assessment output metrics are density and stock estimates by sex and size group. There are high uncertainties in the estimates and ground type effects are likely to be significant although the survey is thought to be effective in cleaner ground areas. A Bayesian approach was tried in 2008, which provided some information on uncertainty and suggested that the population of males is over-estimated. The method allows incorporation of zero densities in the estimation, whereas previously these were accommodated in a log transformation by addition of a constant, which was biasing the assessment. Dividing the data into zero and non-zero observations and treating them separately may be better. The other big issue for assessment is the effective fishing area of traps, which is thought to vary with topography in addition to weather, bait, trap saturation and behavioural interactions.

Smaller crabs and females are more aggregated and generally in shallower water and moulting and mating occurs in the spring, after which the males move offshore to depths of up to 450m. King crabs in Norway have two mating seasons before they reach the minimum landing size (MLS) and there are separate quotas in place for males, females and damaged males. A fishery is permitted for females as there were concerns about potential imbalances due to a single sex male fishery and it was noted that the size of females declined even when there was no fishery for them. There is a higher uncertainty in the female stock estimates which assume a 50:50 sex ratio as evidenced by surveys.

Size and spatial distributions from surveys are used to provide indices for the fishable stock and two separate pre-recruit age classes. Commercial catch data are not sampled for size, but the mean weight of large male crabs in the landings is estimated and has declined in recent years as a result of high exploitation.

The quota system was recently changed from a quota based on numbers of crabs to a quota based on weight. The most recent quota was not taken and is thought to have been over-estimated due to the use of the mean catch weight from previous years. High-grading results in the catch weight being much higher than the stock weight and there may also have been a decline in mean stock weight. There is high selection at sea with 90% of the catch being discarded due to the MLS and high grading of large males. Catch data are reported as weight, because this is more easily monitored from sales notes and reported mean weights tend not be accurate, resulting in actual landings that consisted of higher numbers of crabs at a lower mean weight than reported. Time lags between assessment and quota setting may exacerbate errors in estimation of stock size, with the usual effects to be underestimation of stock sizes on upward stock trajectories and overestimation on downward trajectories.

The quota is set on the basis of taking around 20% of the mature stock as a target, but as the legal size limit is above the size at maturity this equates to 50% of the legal male stock and 15% exploitation rate on the mature stock. Last year's quota (which was over-estimated) was thought to represent around 75% to 80% of the legal male stock. The basis for these reference levels of exploitation was a dynamic length structured model, of the type developed by Zheng (1995; 1998).

The fishery is an all-year fishery with the quota year running from 1 March, but the main fishery starts in September as better quality crab become available, catches decline in late October and November, but improve again in December. Experienced fishermen know this, but inexperienced fishermen may experiment during the period of low catch rates and end up getting poorer catches and losing ground in the better areas that they were holding previously, and ending up on marginal ground for the remainder of the season. Catch rates are therefore widely dependent on fishermen's behaviour and may not be indicative of abundance.

An acoustic tagging programme is planned to ascertain migratory patterns and clarify whether, or not, king crabs can store sperm and spawn multiple times from one impregnation. 'Podding' mounds have been observed with very clumped distributions in shallower water and they are believed to be related to improving larvae dispersal.

Commercial LPUE data are not used because of concerns over their reliability. It is a new fishery with unstable fleet structure, developing fleets and fishermen's behaviour may be evolving, and the quality of data from commercial reporting may be questionable. Incentives (payment or quota) could be used to improve compliance with the reporting system, but there may be implications of such an approach. New fishermen entering the fishery are thought to be more compliant and make more reliable returns in order to ensure quota, while returns from more experienced fishermen tend to be of poorer quality. VMS has been found useful for monitoring the activity of the larger vessels showing an expanding distribution as the fishery developed followed by contraction back to the more productive fishing areas. Some data are available from fishery independent trap surveys, but these have become less useful since the development of the commercial fishery. Norway also uses a 'reference fleet' to monitor trends in their fisheries. The current reference fleet has two or three vessels which participate in the king crab fishery, but this is considered too few to provide a reliable index for the fishery.

2.4.3 Snow crab in Newfoundland

There is an ongoing process of developing tools for monitoring and assessing the fishery, which started by using CPUE data and tagging information along with Leslie and Petersen analyses, which estimated very high exploitation rates (in the region of 100% in some areas). Inshore surveys are carried out and provide an index, which can be compared against fishers catch rates which are available from logbooks, observer reports and quayside landing reports combined with VMS data. The offshore surveys are multispecies cruises using Campelan trawls and there are some concerns regarding the influence of seabed topography on catch rates, as well as some year effects in the survey time series, however the survey provides a swept area based time series of harvestable biomass stock indices. Fishermen in particular have expressed doubts regarding the utility of the survey index, so there has been increased use of observers. Observer discard rates can be important as they provide information on the proportions of juvenile and soft crabs in the catch and protection of these provide a basis for management of the TAC. Discard mortality caused by mishandling including dropping onto hard surfaces and prolonged removal from water have recently been assessed (Grant, 2004).

The observer programme achieves around 4% to 5% with a maximum of 7% coverage of the fleet. Although it is mandatory to take an observer when requested, there may be some reluctance to take observers onboard by some skippers and some avoidance by leaving early citing, for example, weather windows. Higher levels of observer coverage are considered preferable. Observers report when the proportion of soft shelled crabs rises above 20% and at this point they stop biological sampling (length measurements) and focus on determining discard rates as a priority. Observers determine the shell state, by applying moderate pressure to the underside of the claw which causes it to bend or break if soft. When the proportion of soft shelled crabs exceed 20% a surrounding area of 7nm X 10nm is closed to fishing. Quota is not usually a problem, but catch rates and quality issues due to soft shell can be significant. Discussions with managers relating to the possibility of reducing the proportion of soft shell triggering closure to 15% are ongoing. The 20% threshold originated in the Gulf of St Lawrence fisheries and is thought to have little scientific basis. However, a 15% trigger would lead to frequent closures, so the opening date of the season has been moved earlier to allow more time to take the quota, before the season end in June. There may be a test fishery to check the proportion of soft shell before the fishery opens fully. Size frequency information is available, typically in excess of 200 000 measurements per annum, but these data, collected by observers do not include claw measurements, so it is not possible to determine whether crabs have completed their terminal moult. Width distributions and a width weight relationship are used to estimate the mean weight in the catch. Observers ignore the first 5 pots in a string when sampling as these may move around on the seabed and tend to have lower catch rates (end effects). Typically there may be around 40–50 crabs per pot.

LPUE trends are available from commercial logbooks and observers reports as well as quayside landings data divided by VMS based data for hours steaming at <3 knots.

No width sampling is carried out on the quayside. Combined indices are plotted for inshore and offshore fisheries areas along with additional fishery independent information from standard and small-meshed pots surveys. Commercial fishermen are paid to carry out a grid based pot survey with standard bait and soak times during autumn. This can be used to provide a biomass index based on estimates of effective area fished per pot and the grid coverage. A few small-meshed pots are also fished to provide estimates of under-sized and small-clawed crabs. These small-meshed pot surveys provide a limited recruit index with a 2–3 year lead-in to the fishery for some crab management areas.

In all the following data are used for stock assessment:

1) 4 abundance indices (commercial logbooks, observers, landings/VMS, survey)

2) Length frequency distributions

3) Stock biomass estimate

4) Recruit index

Growth and recruitment studies have been carried out using small meshed pots and T-bar tagging studies, and it has been demonstrated that primiparous females can mate. Crab that are 70mm+ are thought likely to 'skip' a year before moulting and recruiting into the fishery, which has a MLS of 95mm and is male only as females are generally <85mm in carapace width. There is no biological basis for the MLS, because size at terminal moult varies widely and maturation can occur at sizes above 40mm. Size at maturation also varies with abundance and the proportion of males going into terminal moult prematurely varies widely, possibly in response to temperature and abundance. Growth data are still uncertain and there are problems with integrated modelling. Other research is looking at survival rates and the potential for trap escape gaps, etc. Bitter crab disease (BCD; (*Hematodium sp*)) has been quite extensively studied and causes serious problems in the fishery, but other diseases are also now being looked at. Tagging studies have suggested that BCD is 100% fatal and fishermen are required to land diseased crab, which are not counted against quota. BCD sporulation coincides with the main moult period for snow crab and it is thought likely that infection may occur during the moulting process.

Recruitment is not well understood, but there is a theory that pre-recruits come up onto the Grand Banks from deeper water, and that environmental effects are very important. They may need cold water for successful settlement, but warm near bottom water may be preferable for growth.

Landings may occur at night and there may be some misreporting by species. VMS can be helpful in identifying when vessels are hauling, but high speed hauling may occur. Systems that monitor the speed of the block may provide an alternative means of monitoring fishing activity.

At present a continuing decline in catch rates is forecast due to low recruitment and current high exploitation rates will delay recovery of the stock and yields. A stock advisory report (SAR) is prepared (annually) and there is a formal mechanism for presentation of the assessment to stakeholders and receiving their feedback on the assessment and the implications for TACs. The TAC is not changed in either direction unless there is strong evidence, but when it is changed, the changes are substantial. There are no benchmarks or reference points other than the soft shell threshold and previous TACs. Historical experience has included large TAC cuts following 'poor years', that have subsequently been thought to be largely attributable to year effects due to poor weather.

Seasonality differs in different areas, but generally similar data (swept area biomass estimates from trawl surveys) are used for stock assessment and management. Change in ratio and index removal methods have been applied elsewhere (Dawe *et al*, 1993). Reference points include no female harvesting and maintaining the proportion of females carrying eggs above 15%, it is generally much higher than this, often around 90%.

2.4.4 Edible crab (France, Ireland, Norway, Sweden, UK)

LPUE data in some form are available from all countries, although mainland Scotland may be limited to EU logbook data (effort may be available only as days fished, as pots set is not a mandatory field) and there are doubts regarding the quality in some areas. Aggregate LPUE indices based on days fished have limited utility as the landings tend to be driven by the largest vessels and effort by the smaller vessels. However, individual vessels' LPUE trends may provide useful indices, particularly when the number of pots fished is available. The UK has individual vessel data available from EU logbooks for >10m vessels since 2000, and in England and Wales from <10m vessels since 2006. Scotland lacks effort data although EU logbooks will be available for >10m vessels. In Shetland, all vessels submit logbooks with daily catch and effort data.

Ireland has data from individual vessels including the numbers of pots worked by vessel size and type for the offshore fishery, but not for the inshore fishery, although a voluntary logbook scheme is in place. The numbers of pots being worked in Ireland has increased dramatically with large offshore vessels working 2000 pots (1000 per day) five years ago, but increasing this to around 5000 pots in total at the present time. A similar trend has occurred for some vessels in the UK.

In France, all vessels must provide logbooks and there is a programme to integrate different data collection programmes, such as the logbook schemes and calendar of activity that is collected for smaller vessels. Under 10m vessels report weekly for all species and all gears and the data are compiled by a privately operated company. The quality of data varies regionally. Effort data are available in terms of pots hauled. There are also some metiers which may take a significant catch of crab (including as a nuisance by-catch, which may be discarded dead) and for which no discard information are available. Trammel net fisheries for sole and tangle net fisheries for anglerfish are examples and similar fisheries exist on the English coast of the Channel. EU technical measures specify a 75kg per day by-catch limit for crab claws, but it is thought that this may be exceeded on occasion.

Norway has no obligatory logbook scheme, but does have a sentinel fleet where around 20 vessels have used experimental traps from which they sample and record catch rates at the start and end of the fishery. They also record discard rate, sex and take length measurements. Total landings data are available, but effort data are not.

In Sweden >10m vessels (approximately 10 vessels) complete logbooks by gear and hours fished, while for <10m vessels monthly reporting of landings and days takes place. Data for total landings and the numbers of pots used are available. In the Skagerak and Kattegat reporting is by squares, mainly in the coastal area and around 150t is taken by a wide range of gears (including pots, fykes, gillnets and *Nephrops* pots).

It was noted that VMS could also be used to derive an index for fishing effort (for vessels >15m), in a similar fashion to that used in Canadian fisheries, i.e. a count of VMS responses where speed is less than a particular threshold and representative of hauling. Some countries have already investigated using VMS in this manner and VMS data can provide better spatial resolution than standard reporting by ICES rectangle, but at times catch and VMS records may be available at different temporal scales and therefore difficult to match precisely. Where catches could be related to relatively precise VMS positional data, it would be possible to consider some spatially disaggregated modelling including habitat types.

Recruitment indices were available in Shetland from discard and length frequency information obtained through an observer programme. Ireland had a small meshed pots programme and discard information for some vessels, although discard information for inshore vessels was not considered reliable. There were no directed towed gear surveys providing quantitative information, although some information may be available from groundfish surveys. It was suggested that pre-recruit surveys needed to take account of both season and the shell condition of the crab, because not all pre-recruits will moult annually, particularly in areas where large size limits are in place. A simple coding system such as u: undersized, w: white, c: crippled (legs or claws missing) and d: discard could form the basis of a monitoring system. Pre-recruit information would be of major benefit to both stock assessment and management, providing the option of using the 2-stage Delury method (catch survey analysis, CSA) for assessment and providing managers with an indication of potential future prospects for crab fisheries.

Ireland had developed automated monitoring systems for discards based on video recordings of 'nicking' and conveyor belts to the vivier tanks or discards chute. An alternative counting system required crabs to be discarded through a hoop mounted on the vessel's gunwale. Discards rates varied widely seasonally and in response to grading practice and market opportunities. In some cases high grading took place to provide processors with better quality crab and the live trade received lower quality, but this was not always the case.

Size distribution data were available for all countries and provide a basis for steady state length based methods, which are tractable, but limited because many of the steady state and dynamic pool assumptions are broken, and they are sensitive to assumptions regarding biological parameters such as growth rates and natural mortality which are poorly estimated for edible crabs.

Depletion methods have also been used with crabs, but on some occasions released crabs appear to remain static for some time. Such experiments have also provided estimates for effective fishing radius of a pot at around 27m (UK) and 20m (Norway).

2.5 ToR e: Review growth rate data and other biological information that is required for providing standardised indices and for analytical assessments

2.5.1 Growth and movement data from tagging studies

2.5.1.1 Background

Growth parameters are key inputs to stock assessment methods. There are a multitude of historical tagging studies for most crab species exploited within the ICES region which have produced estimates of growth parameters, and a series of recently-started tagging programmes for *Cancer pagurus* had suggested that it was an opportune time to assess and review growth parameters for the various species and the methods used to calculate those growth parameters. The WG also considered the implications for assessments of the uncertainty surrounding growth parameters. Although the emphasis at the WG was on the estimation of growth parameters, tagging studies also provide evidence of movements of juvenile and adult crabs, and for some species or stocks, data on movements were also presented.

2.5.1.2 Brown crab (*Cancer pagurus*)

2.5.1.2.1 England and Wales fisheries (with general comments on methodology)

Crab growth can be modelled using continuous models such as the von Bertalanffy (1938) growth curve, or using probabilistically framed models for moult frequency and moult increment to directly capture the discontinuous growth exhibited by individuals.

Although not capturing the discontinuous growth of individuals, continuous models are considered to approximate population growth and they permit the transformation of length to age and thus the application of steady state models such as length converted catch curves, length cohort analysis (LCA) and length structured yield per recruit modelling. Although many of the assumptions of these models are violated by crab life history and biology and spatial structuring of their fisheries, they provide a tractable means of estimating some population and fishery parameters and may therefore have utility.

The von Bertalanffy curve can be fitted straightforwardly by plotting change in length against length (Gulland & Holt plot) and fitting a linear relationship where K is the negative of the slope and L_∞ is the intercept on the x axis (Figure 2.30). However, the inability to directly age crabs routinely means that few data are available to estimate growth rates and growth parameters may be poorly estimated. Table 2.10 provides a number of von Bertalanffy growth parameters that have been estimated for crabs in European waters. In several cases L_∞ has been fixed *a priori* at a size considered representative of an old crab and only K estimated. Plotting the von Bertalanffy growth curves relating to these parameters (Figure 2.31) indicates that with 2 exceptions the curves are very similar during the first 7 years of life and thereafter tend to fall into two groups dependent on L_∞. If those with fixed L_∞ are not considered there may be evidence of an L_∞ in the region of 230mm-235mm for males and around 210mm for females.

However, as estimates of crab growth parameters have high levels of uncertainty and length cohort analysis (LCA) and per recruit models are sensitive to variations in growth parameters, caution in interpretation of the results from such analyses is necessary.

Models that explicitly capture the discrete growth pattern of crabs have been developed and applied by a number of authors. These are usually framed in terms of moult increment (the amount by which a crab grows when it moults) and moult frequency (how often a crab moults or the proportion of the population moulting).

Data for moult frequency and increment can be obtained from tagging studies or aquarium experiments. The former may introduce biases through a number of causes and although tags designed to persist through the moult have been developed, tag loss may still cause problems. Data obtained from aquarium experiments may be useful, but there are always concerns as to whether or not results are truly representative of the wild situation.

Moult increment has been modelled as a linear function of pre-moult size in both absolute and relative terms, and at times using weight rather than width (e.g. Bennett, 1974). Different authors have chosen to use different error distributions, for example Bennett (1974) used normal errors on relative growth increment, Latrouite & Morizur (1988) used normal errors on absolute moult increments, while Zheng *et al.*(1995; 1998) used gamma distributed errors on absolute moult increments. Fitting these models to Bennett's (1974) data shows that all models were similar within the range of the data points, but that they differ markedly in characteristics in the extremes (Figure 2.32).

Annual moult frequency has also been modelled in a number of different forms, with Bennett (1974) using a log linear relationship on weight (i.e. ln(mf+1) =ax+b), Latrouite & Morizur (1988) assuming a linear relationship on width and Zheng *et al.* (1995; 1998) using a reverse logistic model. Within the range of the data the reverse logistic fits quite well, for females especially (Figure 2.33), but this constrains growth to a maximum of one moult per year, which is not the case for small crabs.

This model may therefore be appropriate for modelling growth in the size range captured by the commercial fishery, although there may be considerable uncertainty associated with very low return rates for large crabs that have moulted, but it breaks down if extended to smaller crabs. Per recruit models expressing the percentage of virgin spawner- or egg- per recruit should take account of all potential spawning potential and may therefore need to include smaller sizes. Recent work for the EU POORFISH project explored this type of approach and investigated a wider range of models for edible crab moult frequency, extrapolating them to small sizes (Figure 2.34). As noted previously the reverse logistic fits well in the data range, but is implausible for small crabs, while at the other extreme a linear model on log width is broadly plausible over its whole range, although not fitting particularly well in the data range. Whether one model should apply to the whole life-cycle is also debatable, as growth is likely to change with maturity and sexual dimorphism becomes more apparent with size in edible crabs. Incorporating a length weight relationship to base growth on weight (e.g. Bennett, 1974) may introduce more biological realism, but over a large size range the length weight relationship may also breakdown and introduce bias.

Moult frequency and moult increment models are often probabilistically applied to the population being modelled, i.e. the probability distribution is applied to proportions of the population at any one size. Thus although framed in probabilistic terms, they provide deterministic rather than stochastic output. Often, rather than applying the models dynamically at run time, transition matrices will be estimated beforehand and used during the modelling process. In such cases the moult frequency model would be expressed as a vector specifying the proportion of the population moulting at each size class, while the moult increment model is expressed as a transition matrix specifying proportion of the population at each post-moult size for each pre-moult size.

Moult increment tends to be better estimated than moult frequency because each moulting crab provides a data point for moult increment, whereas this is not the case for moult frequency. For moult frequency several moulting crabs are required to provide a single point for proportion moulting at a given size, and some means of taking account of time between growth episodes is also required (e.g. the anniversary method), which may require exclusion of further data. As a result data on moult frequency tend to be scarcer. In addition, biases introduced through, for example, tag-loss, low recapture rates for large crabs or non-reporting are more likely to influence moult frequency.

Table 2.10. Some von Bertalanffy growth parameters estimated for European waters.

Area	Sex	K	L_∞ (mm)	Source
Shetland	M	0.188	234.3	Tallack, 2002
Shetland	F	0.224	212.2	Tallack, 2002
North Sea	M	0.196	240	Addison & Bennett, 1992
North Sea	F	0.191	240	Addison & Bennett, 1992
English Channel	M	0.252	209	Cefas, unpublished. Moult model in observer length range
English Channel	F	0.144	198	Cefas, unpublished. Moult model in observer length range
English Channel	M	0.181	240	Cefas, unpublished. Constrained fit to moult increment data
English Channel	F	0.069	240	Cefas, unpublished. Constrained fit to moult increment data
English Channel	F	0.168	240	Cefas, unpublished. Constrained fit to moult increment data (3 points only)
Channel (France)	M	0.39	232	Latrouite & Morizur, 1988
Channel (France)	F	0.25	210	Latrouite & Morizur, 1988

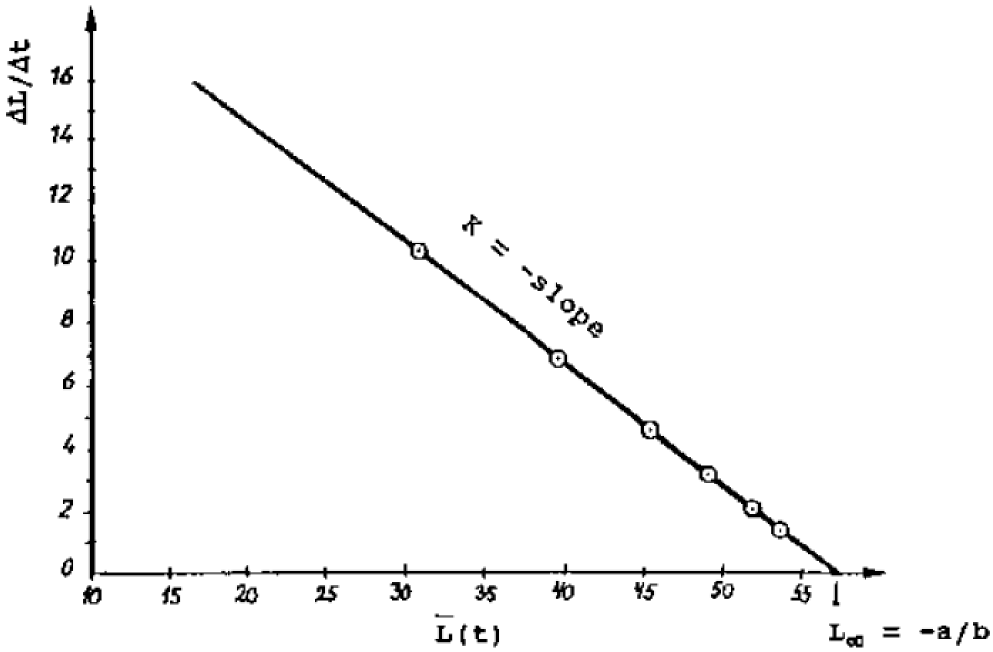


Figure 2.30. Gulland & Holt plot (from Sparre & Venema, 1998).

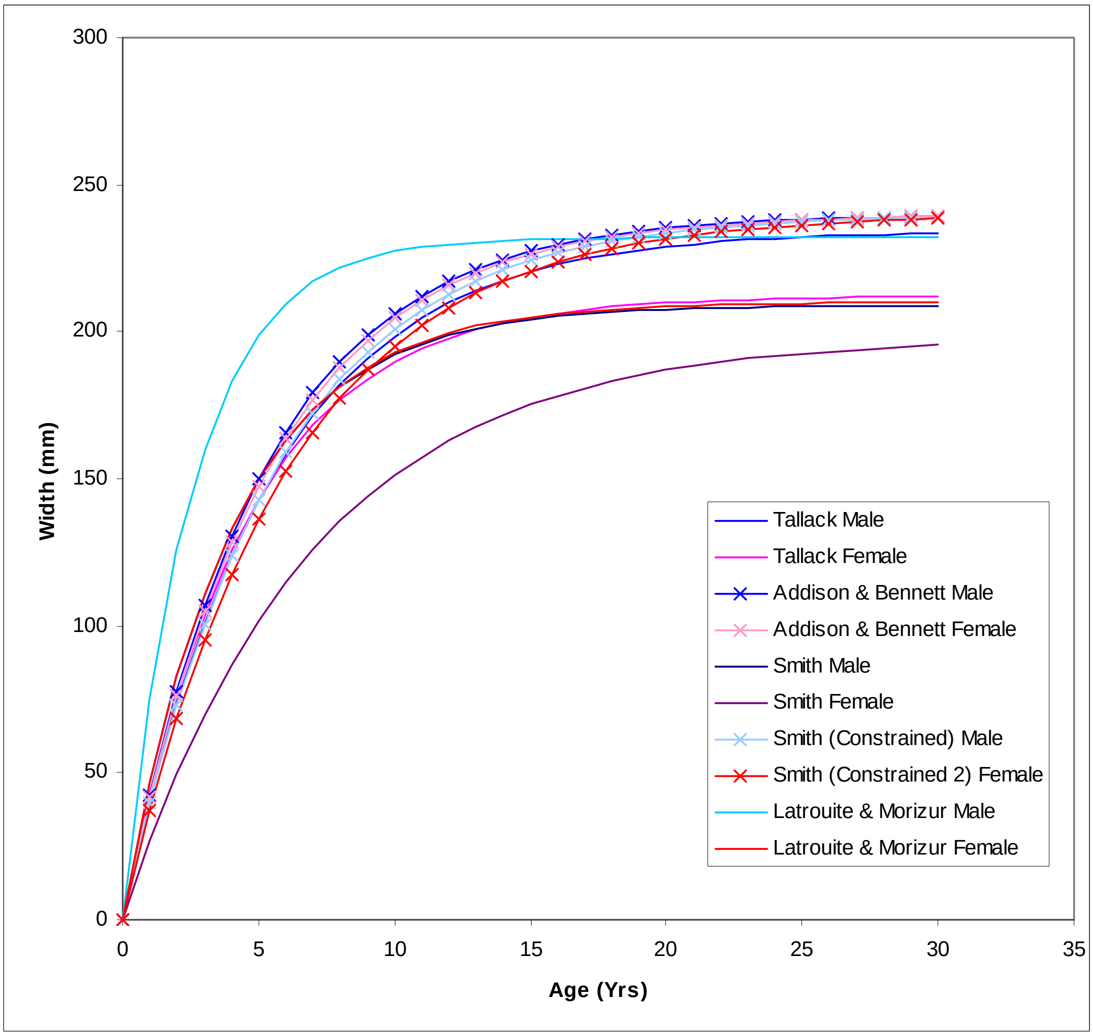


Figure 2.31. Von Bertalanffy growth curves for edible crabs. Lines marked with Xs indicates L_∞ was fixed a priori, red colours females, blue colours males.

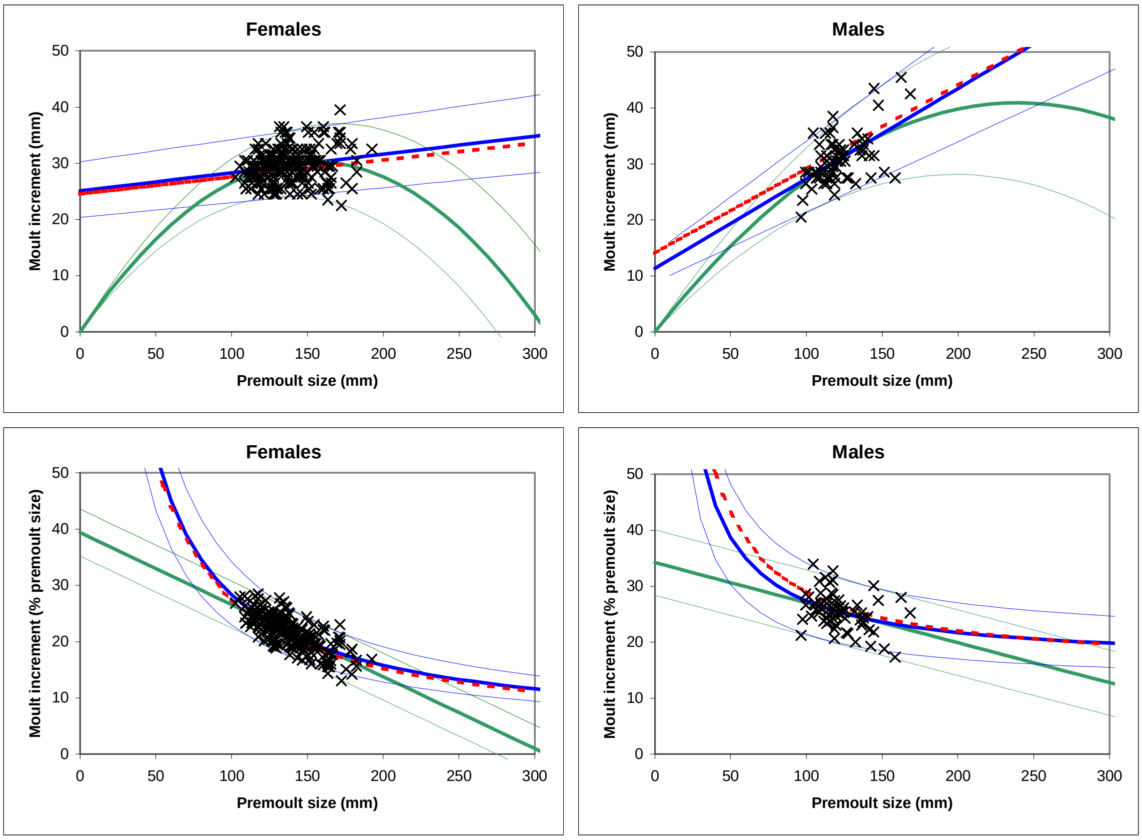


Figure 2.32. Moult increment models fitted to Bennett's (1974) tagging data for edible crabs. Top row: absolute increments, bottom row: relative increments. Blue: Linear model on absolute size with gamma errors, red linear model on absolute with normal errors, green: linear model on relative increments with normal errors.

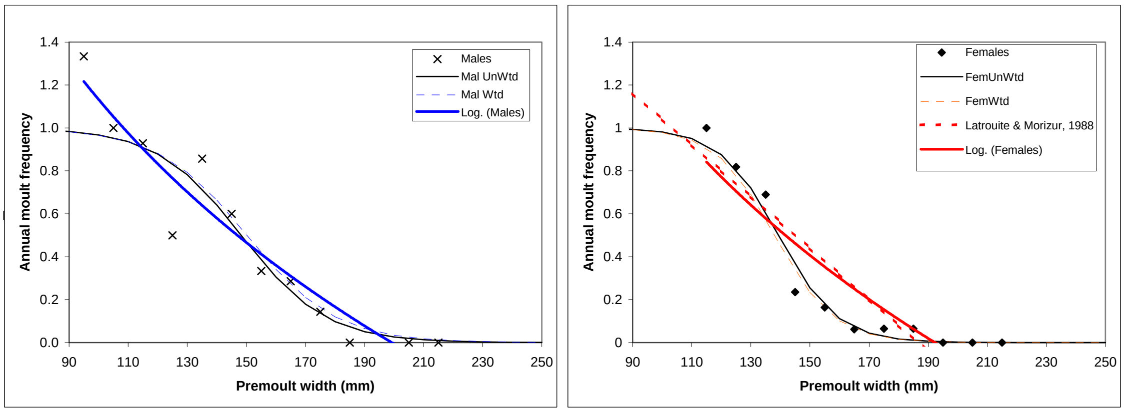


Figure 2.33. Moult frequency models fitted to Bennett's (1974) tagging data for edible crabs.

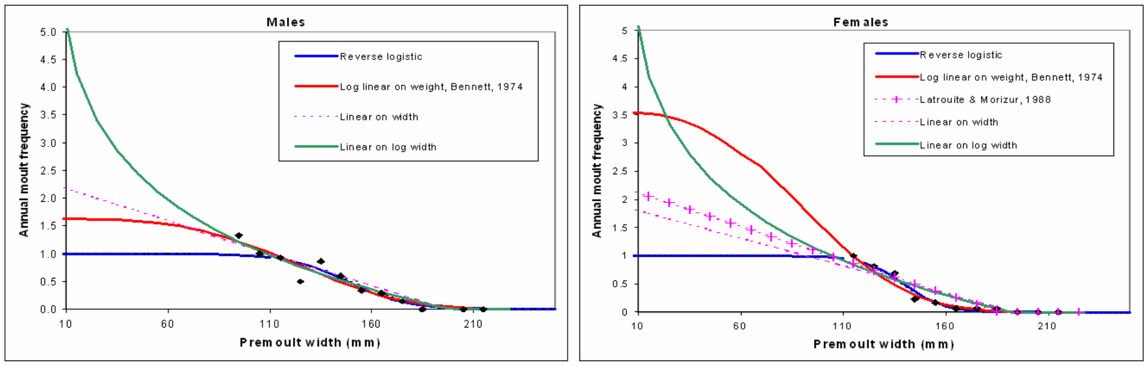


Figure 2.34. Range of moult frequency models fitted to Bennett's (1974) tagging data for edible crabs.

2.5.1.2.2 Scotland

A new tagging programme started in Scotland in 2008 to investigate the movements of brown crabs captured on inshore and offshore grounds. The study is a joint venture, involving the fishing industry funded under the Scottish Industry/Science Partnership (SISP). The aim is to obtain information on migratory and life history patterns of the male and female brown crab to the north west of Scotland. The study is using T-bar tags, but to date there are very low returns. A Working Paper describing the study to date is attached in Annex 3.

2.5.1.2.3 Shetland

Growth parameters have been determined for both brown and velvet crabs from the Shetland Fishery (Tallack, 2002). Various methods were used to collect growth data including; catch surveys, market surveys, spat bags, shore and cliff surveys for juvenile sampling, in addition to observations on both laboratory held and sea caged individuals and a tagging project. Various methods were used to determine L_∞ and K values, including a "top ten" method which used a mean of values from the largest 10 individuals, Wetherall plots and Ford-Walford plots. Those values used for assessment processes are detailed in the following sections, and further information on how they were derived is described in Tallack (2002).

Length Cohort Analysis – *Cancer pagurus*

Growth data used for the LCA analysis is from Tallack (2002). Limited moult increment data (n=42) were obtained from a number of sources (in captivity and in situ, via tagging, from fishermen's creels and on the shore). The mean percentage increase after moulting was reported as 25.3% for both males and females. Estimations of growth were obtained using a Pearson method. Length frequency data were obtained from shore and commercial catch surveys and were examined for each sample and year separately so that only one year's moult period was included in each size frequency plot. Size modes for larger individuals were not well defined. Annual size modes were plotted as Ford-Walford plots to determine K with L_∞ estimated using Wetherall plots (Tallack, 2002).

The input parameters for the LCA and their sources are shown in Table 2.11. The results of the LCA analyses are shown in Figures 2.35 and 2.36.

Table 2.11. Input data for brown crab length cohort analysis.

Input parameter	Female	Male	Data source
Size frequency data			Commercial fishing & Research (2008)
L_∞ (max. individ. size)	227	246	Estimated from Powell Weatherall plots
K (rate of growth)	0.224	0.188	Tallack (2002) growth work
M	0.256	0.242	Tallack (2002) Longevity derived
F	0.174	0.406	Tallack (2002) $F = Z\text{-}M$
a (size weight relation)	0.00024	0.00008	Tallack (2002)
b (size weight relation)	2.895	3.166	Tallack (2002)

Female Brown Crabs

At current fishing levels (0% change) and an estimated natural mortality of $M = 0.256$, the brown crab fishery appears to be operating below the maximum yield per recruit for female crabs (Figure 2.35). The long term predictions suggest that changes in fishing effort would have a limited effect on landings, with a predicted increase in landings of 2.9% associated with a 30% increase in effort. A 30% decrease in effort is predicted to result in a 9.9% increase in the total stock biomass in the long term. At lower levels of natural mortality ($M = 0.1$) the fishery appears to be exploited at beyond the maximum sustainable yield at current levels of fishing effort.

Predictions were made on the potential effect of raising the minimum landing size for brown crabs from 140 mm to 150 mm carapace width. There were only small differences in the long term predictions of yield or biomass with this change in minimum landing size and these were only apparent with significant changes in fishing effort (Figure 2.35). This was true for all levels of natural mortality investigated.

Male Brown crabs

The long term predictions of yield and biomass for male brown crabs (Figure 2.36) were slightly different to those produced for females, although the predicted natural mortality was lower for males ($M = 0.242$). At the current levels of fishing effort the fishery was shown to be operating at just beyond the maximum yield per recruit. It is predicted that with a decrease in fishing effort of 30%, the subsequent long term increase in biomass would be 13.4%. If natural mortality is lower than predicted (e.g. $M = 0.1$), the fishery could be well beyond the maximum sustainable yield. Predictions made around a higher natural mortality ($M = 0.3$) showed the fishery to be exploited at around the maximum sustainable yield.

Predictions on the yield and biomass for changes in the minimum landing size from 140 mm to 150 mm carapace width produced only slight differences in the yield and biomass per recruit curves, and these were only observed with substantial reductions in fishing effort (Figure 2.36).

Tagging work carried out to the west of Shetland (unpublished) has indicated that the brown crab stock in this area are relatively mobile, particularly females, and that individuals travel to areas outside the six mile limit encompassing the regulating order. The extent of the brown crab stock, of which Shetland's inshore fishery is a part, is therefore not clear. It is also apparent that differences in the value attributed to natural mortality have a significant effect on the output of the model, and for these reasons the results of the LCA analysis should be interpreted with caution.

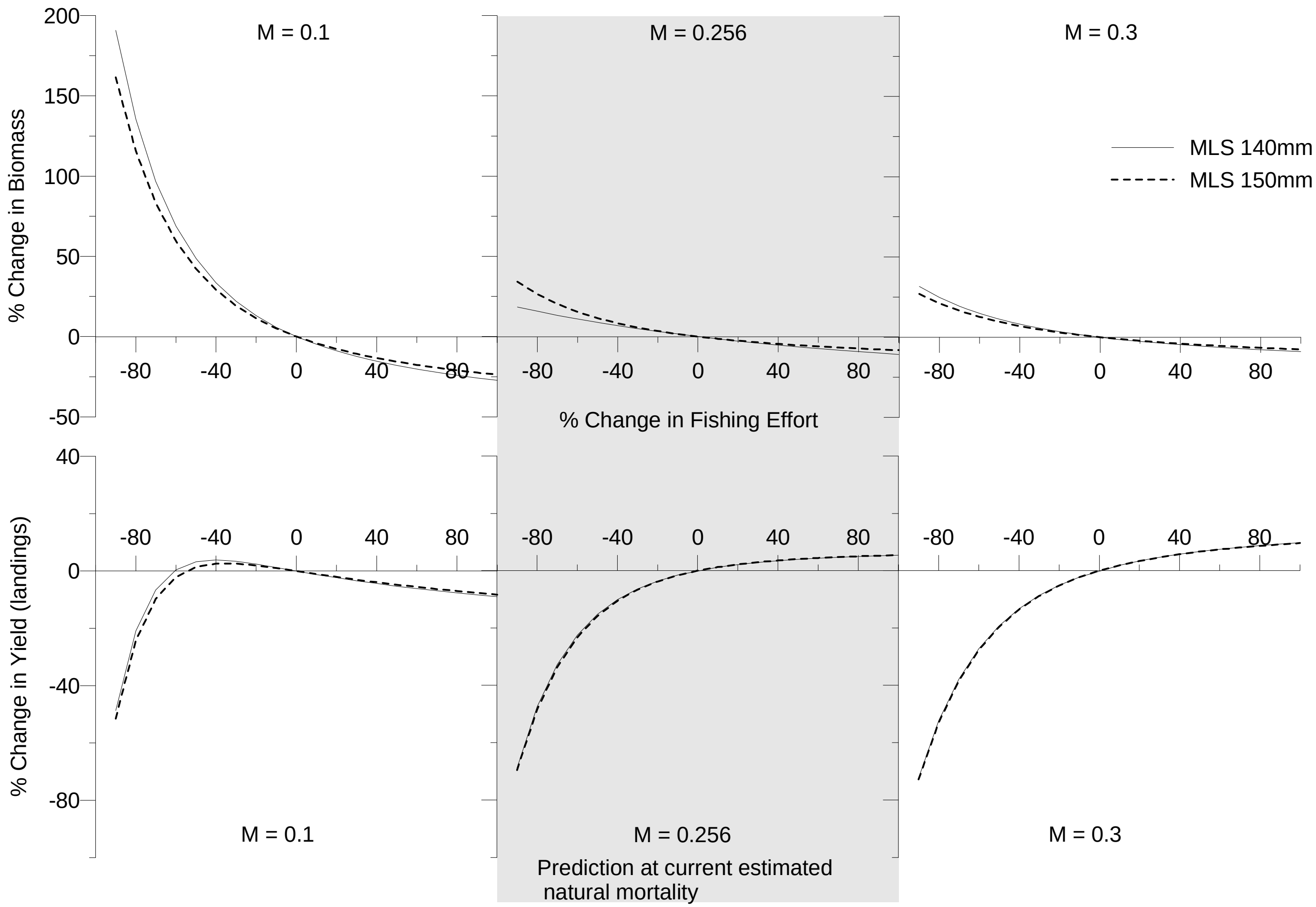


Figure 2.35. Long term predictions of yield and biomass of female brown crab stocks with changing fishing effort at the current MLS of 140 mm, and at a MLS of 150 mm, using the estimated natural mortality M = 0.256 and two other nominal values - M = 0.1 and M = 0.3.

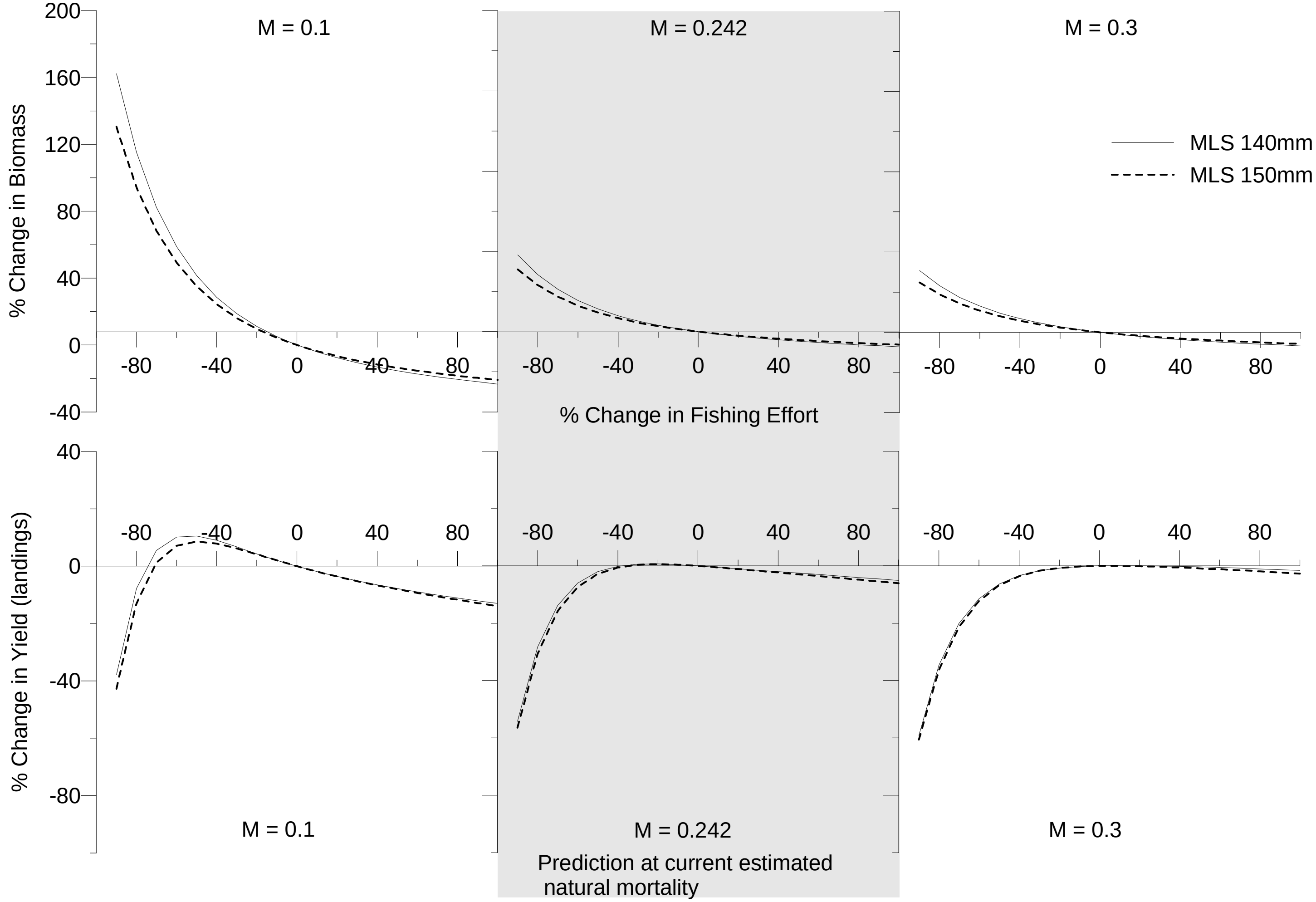


Figure 2.36. Long term predictions of yield and biomass of male brown crab stocks with changing fishing effort at the current MLS of 140 mm, and at a MLS of 150 mm, using the estimated natural mortality M = 0.242 and nominal values of M = 0.1 and M = 0.3.

2.5.1.2.4 Ireland

Tagging of brown crab in Ireland continued during 2006–2007 in inshore and offshore areas (see previous WG reports) of the northwest 'stock' in an attempt to elucidate seasonal movements. Overall, tag recoveries and/or reporting of tag recoveries were very low compared to previous results from Ireland. Although this may be attributable to poor tag retention, previous studies had recorded recoveries many times higher. As crab in the previous and current study moved predominantly to the west/southwest, *a priori* planning had predicted that many recaptures would occur in the North Mayo region. As fishermen from this area failed to co-operate however, the ability of this project to provide novel data on stock structure from tag return data was seriously diminished. Data has re-confirmed that a seasonal movement pattern exists for brown crab in the NW region, and that the stock is mobile in autumn and spring months. As participation from fishermen in all areas could not be guaranteed, a genetic stock identification project with a wider geographic range was conducted with assistance from BIM. Samples were collected from the NW fishery (inshore and offshore), Kerry and Wexford, DNA extracted and subjected to PCR protocols using microsatellite molecular markers. A series of six microsatellite markers were employed. Initial results suggest that there is significant connectivity between 'stocks' around the coast of Ireland, and that in genetic terms they can be considered a single 'stock'. This suggests that further genetic studies of brown crab populations around Ireland for the purpose of defining stock management units would not be of value. Fishing activity is not continuous around the coast and geographic segregation of fleets is apparent. Localised/regionalised centres of abundance that support existing fishing activity are more useful in terms of management units and these are easily delineated in geographic/cartographic terms.

Current synopsis of findings from Irish tagging studies

Tagging studies can provide beneficial data on brown crab seasonal movements, but only when industry is actively involved.

Female crabs in the NW region become more mobile during the autumn and spring, with a general movement to the west/southwest. Movements toward the northeast/east are also observed and these may be indicative that some return migrations occur.

Although the inshore and offshore fisheries of the NW are sometimes considered in isolation (particularly by industry), crabs move freely between the grounds exploited by the sectors.

Genetic variability in crab stocks from around the whole of Ireland is low, and can be considered a single population.

Irish brown crab stocks cannot be divided into rational or realistic spatial management units or regions based on genetic data, and therefore further studies are not warranted at this time.

The spatial discontinuity in brown crab fishing activity along the west coast currently used to divide the resource conveniently into 'northern' and 'southern' stocks would seem appropriate, as although significant connectivity between the 'stocks' in these areas is suggested by genetic data, it seems likely that one could replenish itself without input from the other considering their geographic separation.

Management measures at a more localised scale may still be appropriate, but will not be confined to an isolated 'stock'.

Current Recommendations for Ireland

- Support further tagging surveys for brown crab only if activity is intense, localised and supported by the majority of fishermen in the region/area. Such studies are probably only of application for specific tasks & directed surveys (e.g. assessment exercise, evaluation of disease impact etc.), and are unlikely to yield useful additional data on overall stock distribution.
- Continue to consider NW stock (inshore and offshore) as a single stock management unit.
- Support genetic studies for this species only if significant new data suggest that sub-populations not previously identified (with known markers) are present and biological characteristic relevant to resilience to fishing pressure differ between them.
- Studies that determine the natal source of recruitment to key fishing areas may be of advantage in defining and protecting spawning grounds.

2.5.1.2.5 Sweden

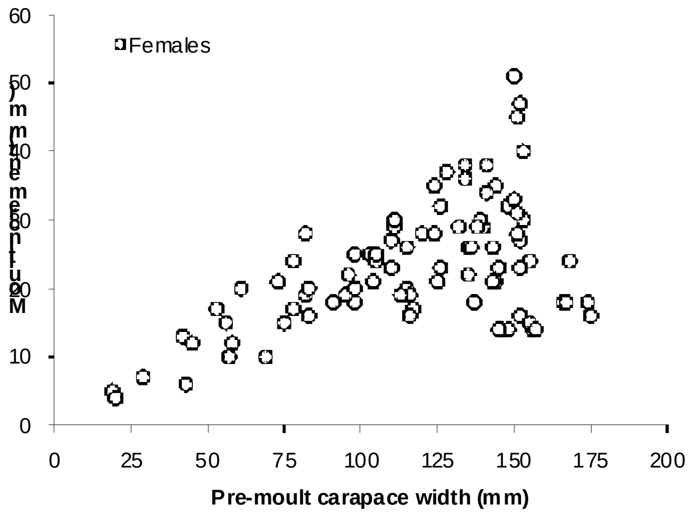
A compilation of Swedish growth data based on i) unpublished mark-recapture data (increment and days) from Hans Hallbäck's mark-recapture experiment in the 1960-70´s ($n_{females}$=65; n_{males}=15), ii) laboratory moultings from Hallbäck (increment) ($n_{females}$=25; n_{males}=20), iii) few moult increments from recent observations on moultings in pots $n_{females}$=4; n_{males}=7 (increment) and iv) length frequency in captures are shown in Table 2.12. Estimations of the natural mortality and the weight-width relationship for females and males respectively, are also shown in this table.

Table 2.12. The estimated growth parameters L_∞ and K by different approaches in Sweden, natural mortality M by empirically developed formulae, and weight-at-carapace width. MR=Mark-recapture.

Sex	**Female**		**Male**	
Location	Kattegat	Skagerrak	Kattegat	Skagerrak
L_∞ Capture data Power-Wetherall Z/K	179; 195 ($n_{>140}$=4308) 0.92; 2.00	193; 212 ($n_{>140}$=3713) 3.28; 5.30	182; 197, ($n_{>140}$=1574) 0.82; 1.63	193; 202 ($n_{>140}$=2649) 2.12; 2.77
Empirical L_∞	217 (5% over max 207 mm CW)			
K MR data Forced Gulland-Holt	0.586 (179); 0.386 (195); 0.263 (217)	0.403 (193); 0.283 (212) 0.263 (217)	0.391 (182); 0.289 (197); 0.214 (217)	0.310 (193); 0.266 (202) 0.214 (217)
L_∞; K MR data Munro`s Fabens Appeldoorn`s	n=54 201; 0.450 212; 0.253 210 ± se 16.7; K 0.260±se 0.08)		n=12 190; 0.603	
K MR data Ford-Walford	0.193 (L_∞ 210) 0.214 (L_∞ 200) 0.241 (L_∞ 190)		0.241 (L_∞ 210) 0.269 (L_∞ 200) 0.304 (L_∞ 190)	
M Pauly (1980) Rikther/Effanov (1976)	0.21-0.25 (9.2°C) (W_∞-L_∞) 0.34-0.32-0.26- 0.21- 0.18 (age of 4-8 years at maturation, resp.)		0.21-0.25 (9.2°C) (W_∞-L_∞) 0.34-0.32 (age of 4-5 years at maturation, resp.)	
Weight –width* a b log a	n=656 0.000194 2.9297±0.038 -3.71±0.084	n=716 0.000284 2.8620± 0.052 -3.55±0.112	n=139 0.00004133 3.2758±0.088 -4.38±0.190	n=348 0.00004890 3.2419±0.061 -4.31±0.130

***Landings, intact individuals.**

The moult increment in relation to the pre-moult carapace width, based on i-iii above, is shown in Figure 2.37.



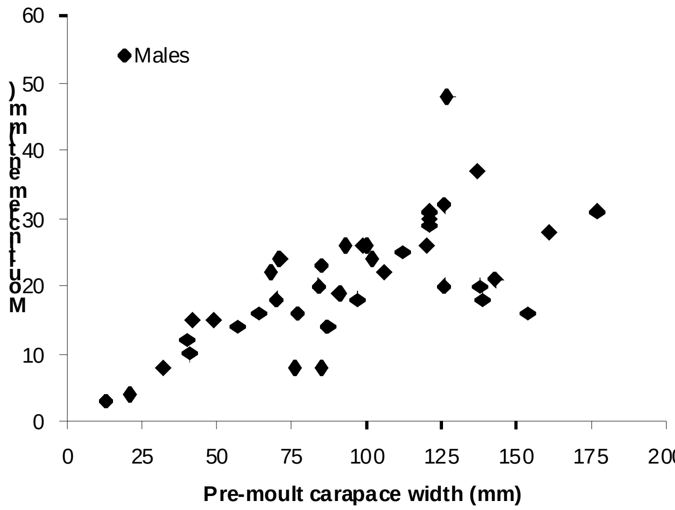


Figure 2.37. The growth increment per moult based on mark-recapture recoveries in Sweden, and laboratory or pot moultings are shown for females (above) and males (below).

2.5.1.3 Spider crab (*Maia squinado*)

2.5.1.3.1 France

In Brittany, the landings of spider crab are quite important and around 4500 tons each year. This fishery is mainly developed on the recruitment and these individuals have not participated in reproduction. Nevertheless, the landings are stable year after year. The minimum legal size and the biology of the spider crab are some of the elements to explain this situation. Various studies have been developed to improve our knowledge on the biology and we present a first synthesis of the results.

Several studies have been planned in order to improve the knowledge of the growth of spider crab. Two types of study have been carried out:

- Estimation of the growth rate from individuals caught and stored in tanks.
- Farming of individuals obtained from hatching in tanks.

From the first experience, a growth rate as a function of the size can be estimated for the moult juvenile to juvenile (Table 2.13). These values are modelled from the different individual growth rate measured (Figure 2.38). These data only include the moult appeared from the first day to the 25th. After this period, a decrease of the growth rate is noted due to the live in tank. It seems that the growth rate decreases when the size increases. No difference is observed between male and female.

Table 2.13. Growth rate as a function of the size.

	Length before moult				
Sexe	20	40	60	80	100
F	46%	42%	39%	35%	32%
M	45%	42%	38%	35%	31%
F + M	46%	42%	39%	35%	32%

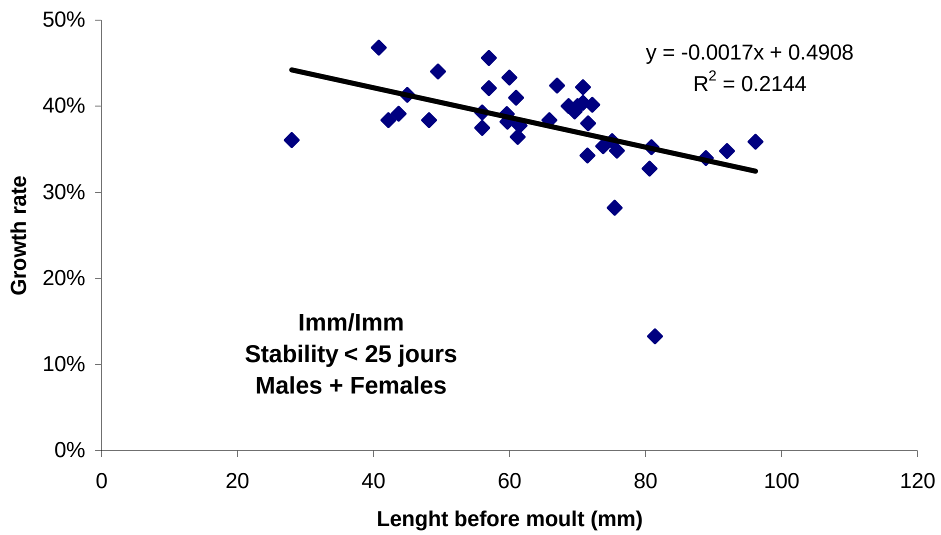


Figure 2.38. Individual growth rate of spider crab in France as a function of the size before the moult.

At the last moult, when individuals become adults, the growth rate is around 30% for female and male when we consider all the data. Nevertheless, the rate is really dependent on length and a distinction between male and female seems to appear (Figure 2.39). These results show that the last moult is not linked to the length. In our experience, the range length is comprised for females between 79 and 110 mm and 83 to 137 mm for males. In consequence, the range length of adult is large and a significant part does not reach the minimum legal size of 120 mm, 27 % in our sample.

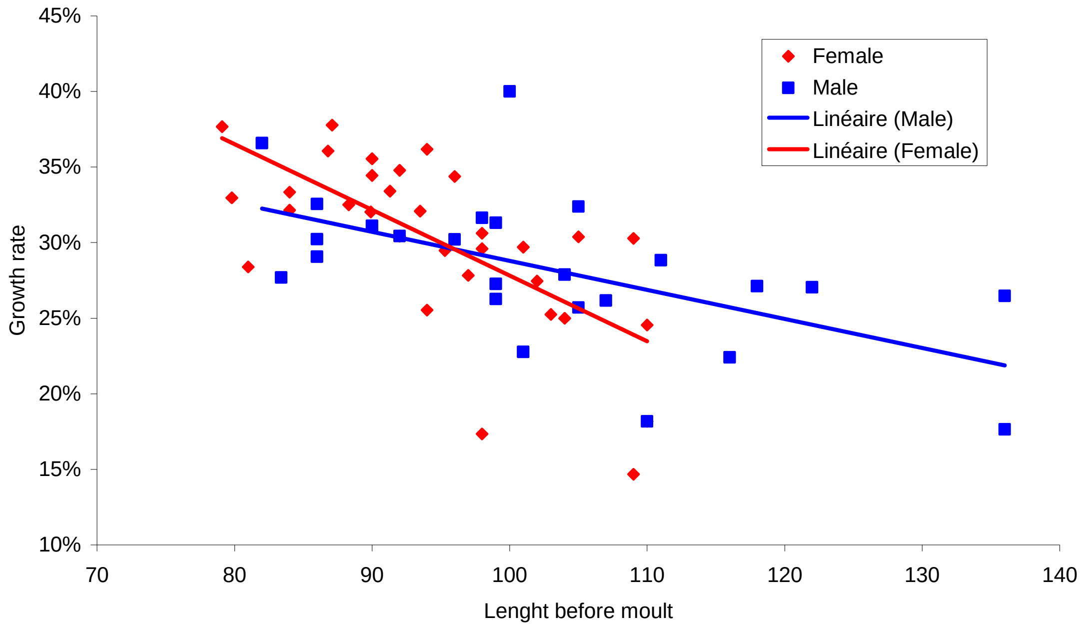


Figure 2.39. Growth rate as a function of length before moult in spider crabs.

In the second study, berried females have been stored in tanks to obtain larvae. After the metamorphosis, as soon as it was possible, the individuals were measured every month. At the beginning, the small size did not permit to follow each individual but the size structure. These data allow an estimate of an average, a maximum and minimum length (Table 2.14). For this group, one or two moults have been noted during the first winter, none during the second (Figure 2.40). A group with a metamorphosis in June 2002 does not present any moult during the first winter (Figure 2.41). From the following of other groups with different date of metamorphosis, it seems that the number of moults during the first winter would be linked to the size.

Table 2.14. Evolution of the size and the number of spider crab after a metamorphosis the first of August 2001.

	Dec	March	May	June	July	August	Sept	Octo
Number	183	153	124	83	51	30	30	24
Mean (mm)	13	21	30	42	50	70	73	86
Min Length (mm)	8	8	11	23	28	45	43	56
Max Length(mm)	36	47	57	68	77	116	100	114
Number of Month	4.2	7.5	9.2	10.2	11	12.5	13.4	14.7

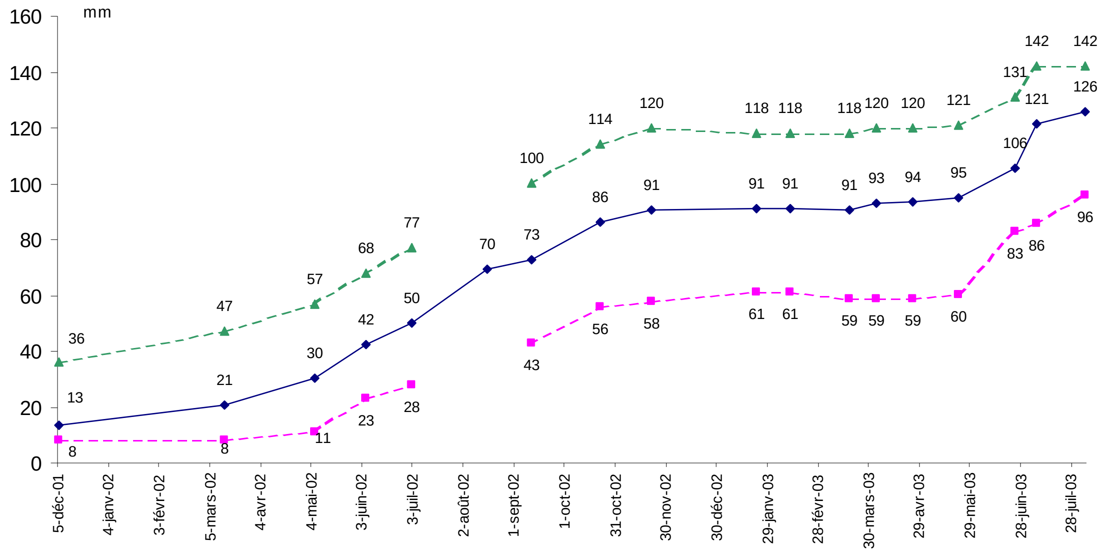


Figure 2.40. August 2001 Group, average, maximum and minimum length along the growth period.

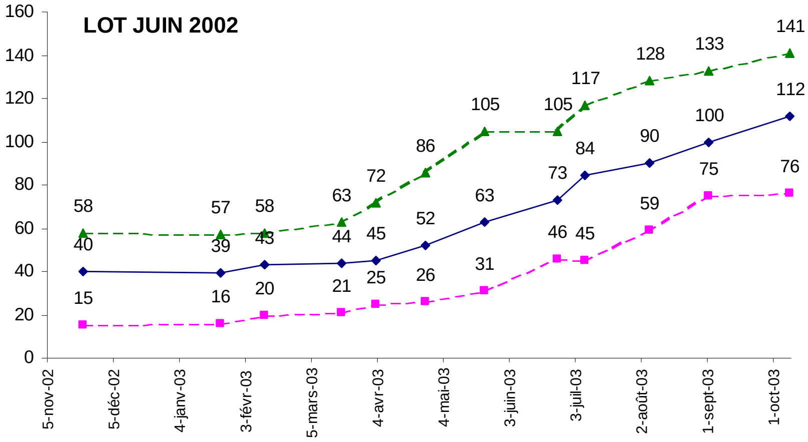


Figure 2.41. June 2002 Group, average, maximum and minimum length along the growth period.

During these studies, the individuals became adults rather than in the natural condition, sometimes after only 13 or 14 months. Nevertheless, the majority was adult the second summer after the metamorphosis.

Proposition of a growth model

These data and results permit to propose a growth model. To develop this model, some assumptions have been established:

- A first length of 2 mm after the metamorphosis.
- A first intermoult period of 4 days.
- An increase of 50% of the intermoult period after each moult.

Using these assumptions and the results of the experiences it is possible to propose an average growth model with 13 moults (Table 2.15). If we modify the growth rate from 1.44 to 1.31 the number of moult is 14 for a final length of 172 mm. This first model and the uncertainties on the assumptions lead to propose a total number of moults from 13 to 15 to lead to adult stage. But we can suppose that large range of size in the adult population can be explained by a difference of moult number or growth rate.

Table 2.15. Simulation of growth from one model.

Period	Length	Date	Rate Growth	Year
Meta	2	01-July	1.5	1
Moult 1	3	04-July	1.485	1
Moult 2	4	10-July	1.47	1
Moult 3	7	19-July	1.455	1
Moult 4	10	02-Aug	1.44	1
Moult 5	14	22-Aug	1.425	1
Moult 6	20	23-Sept	1.41	1
Moult 7	28	08-Nov	1.395	1
Moult 8	38	01-May	1.38	2
Moult 9	53	10-June	1.365	2
Moult 10	72	10-Aug	1.35	2
Moult 11	98	10-Nov	1.335	2
Moult 12	131	01-Mai	1.32	3
Moult 13	172	15-Aug		3

2.5.1.4 Velvet crab (*Necora puber*)

2.5.1.4.1 Shetland Isles

Growth parameters were estimated in a similar way as for *Cancer pagurus* as outlined in section 2.5.1.2.3. The input parameters for the Length Cohort Analysis and their sources are shown in Table 2.16. The results of the LCA analyses are displayed in Figures 2.42 and 2.43. Analysis of size frequency distributions for velvet crabs from commercial sampling and recent survey work (Leslie & Shelmerdine, 2008) has shown that there were some differences in the length frequency and sex ratio recorded between areas. As a result of these differences length frequency distributions have been raised by area to better reflect the differences seen. Length frequency data from 2008 alone was used in the assessment to ensure that data from previous years was not unduly influencing the predictions.

Table 2.16. Input data for velvet crab length cohort analysis.

Input parameter	Female	Male	Data source
Size frequency data			Commercial fishing & survey work (2008)
L_∞ (max. individ. size)	100.1 mm	107 mm	Estimated from Powell Weatherall plots*
K (rate of growth)	0.463	0.463	Tallack (2002) growth work
M	0.576	0.576	Tallack (2002) Longevity derived
F	0.202	0.31	Tallack (2002) $F = Z\text{-}M$
a (size weight relation)	0.0038	0.0011	Velvet survey work
b (size weight relation)	2.42	2.75	Velvet survey work

*** The estimated L_∞ for female velvet crabs from the Powell Weatherall plots was 97 mm, however, to allow the LCA to function properly the minimum L_∞ was set to 100.1 mm. Observations of the length frequency data indicate that this larger size is likely to be a more realistic reflection of Shetland velvet crab population parameters.**

Female Velvet Crabs

Analyses of the velvet crab data indicated that for current levels of fishing effort (indicated as a 0% change on Figure 2.42) and at an estimated current natural mortality of *M* = 0.576 (Tallack, 2002), the model predicts that female velvet stocks are being fished below the maximum sustainable yield (Figure 2.42). The yield per recruit curve, however, shows that in the long term increased fishing effort will not result in a substantial increase in landings, for example; an increase of 20% in effort would only produce an increase of around 1.4% in landings in the long term. This would result in a corresponding decrease of 4.4% in the biomass of the stock. The model also provides long term predictions for two alternative levels of natural mortality if natural mortality is lower than the estimated figure (e.g. *M* = 0.3; Figure 2.42), the stock would be exploited at above the maximum sustainable yield.

A change in the landing size to 75 mm carapace width did not appear to have a significant effect on the output of this analysis, with similar patterns in yield and biomass seen for most levels of predicted change in effort (Figure 2.42).

Male Velvet crabs

The yield per recruit curves produced for male velvet crabs were similar to those produced for females. At the current level of fishing effort (0% change) the fishery is predicted to be operating below the maximum sustainable yield. Any increase in effort would be expected to result in only a very slight increase in landings and a decrease in total biomass in the long term (Figure 2.43). A reduction in fishing effort by 30% forecasts a long term increase in the total biomass of 10.6% and a decrease in landings of 6.8%. At a lower predicted natural mortality of *M* = 0.3, the yield per recruit curve is again more defined, suggesting that the fishery would be exploited at above the maximum sustainable yield under the current levels of fishing effort.

Changing the minimum landing size to 75 mm was shown to have little effect at current levels of fishing effort (Figure 2.43). The largest difference seen in the long term predictions of yield was through significant changes in fishing effort.

The velvet crab fishery in Shetland was subjected to an increase in MLS in 2001 and so may not have had time to reach an equilibrium state since the change, which is an assumption of the LCA model. The model also assumes the fishery and effort are stable and for this population there is evidence that this may not be the case. The LCA model also assumes a steady recruitment so therefore, if recruitment is poor, the yield will appear greater as proportionately more large individuals are caught, resulting in the fishery appearing more healthy than it actually is, and *vice versa*. The differences in the yield and biomass curves for differing values of natural mortality (M) also indicate that the model is particularly susceptible to changes in M. The results of the model must therefore be interpreted with caution.

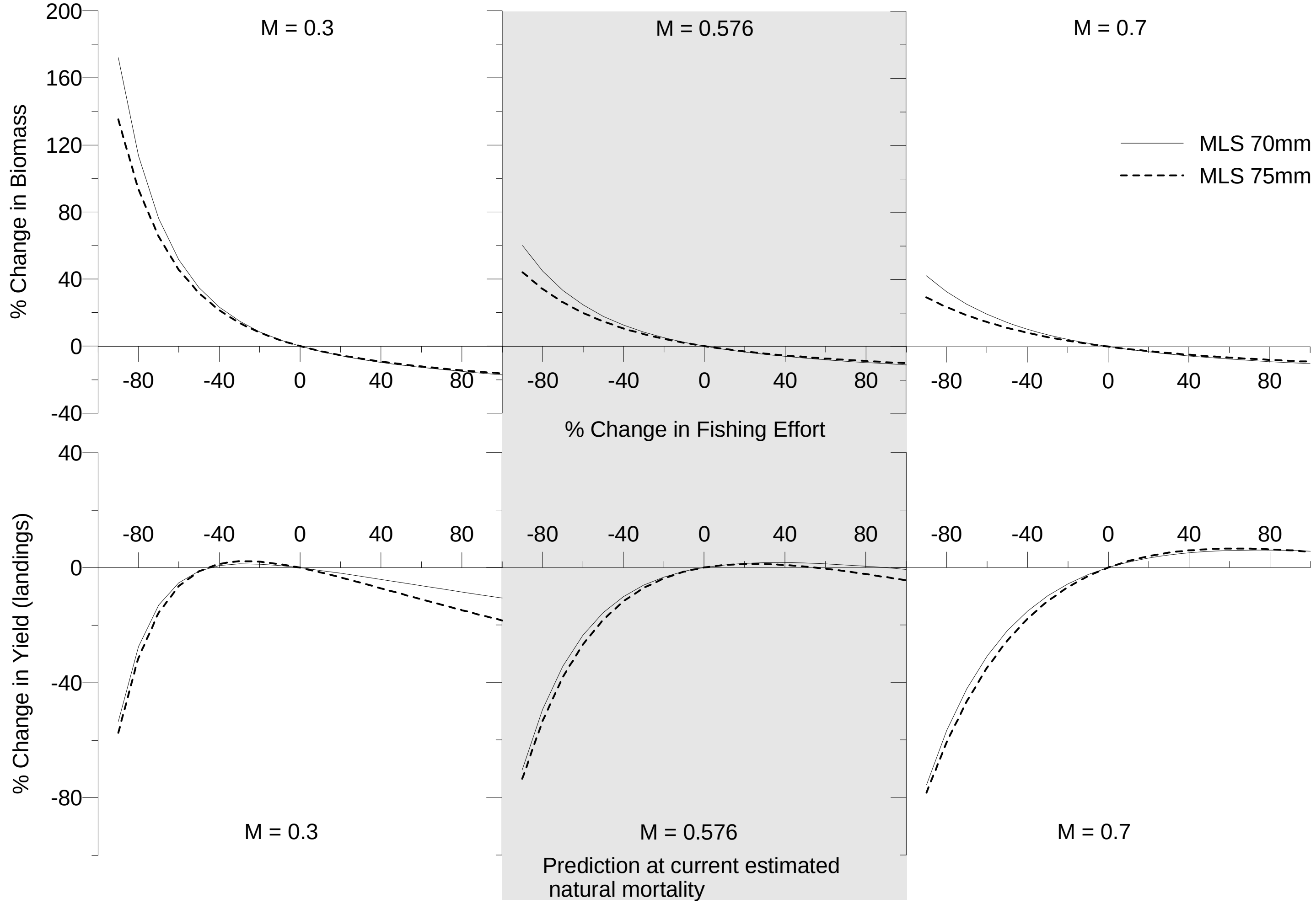


Figure 2.42. Long term predictions of yield and biomass of female velvet stocks with changing fishing effort at the current MLS of 70 mm, and at a MLS of 75 mm, using the estimated natural mortality $M = 0.576$, and other nominal values of $M = 0.3$ and $M = 0.7$.

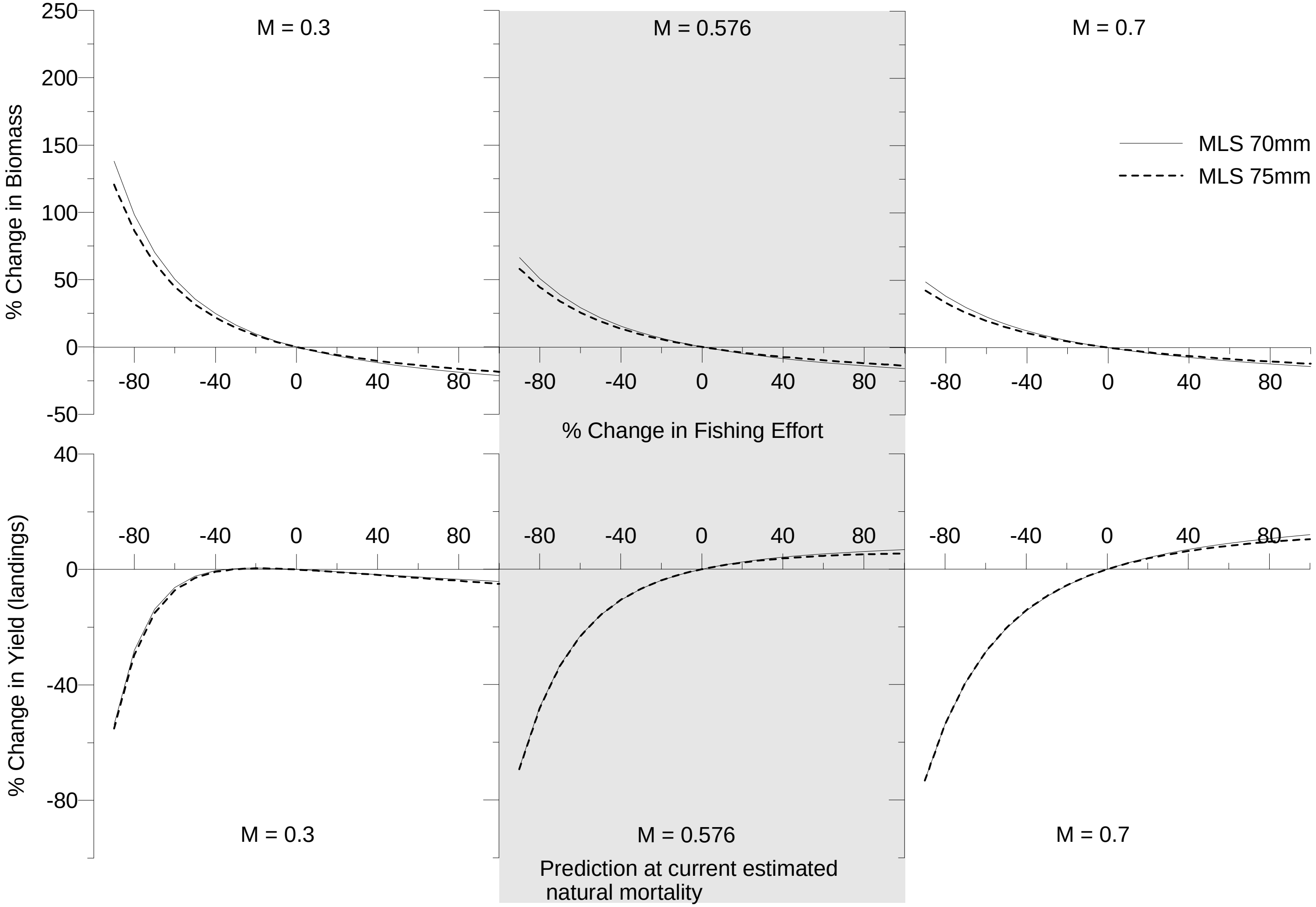


Figure 2.43. Long term predictions of yield and biomass of male velvet stocks with changing fishing effort at the current MLS of 70 mm, and at a MLS of 75 mm, using the estimated natural mortality *M* = 0.576, and using other values of *M* = 0.3 and *M* = 0.7.

2.5.1.5 Red king crab (*Paralithodes camtschaticus*)

2.5.1.5.1 Norway

A programme in Norway, aimed at examining the spread and migration of king crabs and growth increment and moult probability, tagged 12 000 king crabs using T-bar tags released in two areas on the border with Russia between 1994 and 2000 (Nilssen and Sundet, 2006). There were 1200 returns with 500 positive increments. Moult increment varies between male, females and ovigerous females, with much smaller increments in ovigerous females. Using animals at liberty for one moult only in the analysis, a logistic model was fitted to growth data to estimate probability of moulting. From 70 to 120 mm carapace length, the crabs moult every year, but at larger sizes, moult frequency declines and older crabs tended to show skip moulting. There was no evidence of a terminal moult for females. The development of growth curves was not considered necessary, as the growth data are used only to define pre-recruits and recruits for use in a transition matrix model.

2.5.1.6 Snow crab (*Chionoecetes opilio*)

Studies conducted in the laboratory with T-bar tags showed growth increments of 13-20% per annum based on one moult per year. Similar growth increments are observed across geographical areas, but there are assumed differences in moult frequency across areas, with a consequent significant variation in size at terminal moult across areas. The growth data are applied to the size distributions of catch observed in the trawl surveys (i.e. abundance of pre-recruit 1 and pre-recruit 2 stages) to predict abundance for next year's stock and catches incorporating assumptions about when pre-recruits join the fishery, and the proportion of crabs that skip moult. This information can then be used to inform discussions about future quotas.

2.5.2 Recruitment indices

2.5.2.1 Background

Recruitment indices are used in a number of global fisheries to predict future additions to the fished stock and advise management strategies. The WG agreed that such indices could form a vital part of assessment and management of crab fisheries in the ICES region. Such indices may be generated from larvae surveys, settlement or juvenile collectors, directed research surveys using beam trawl or other gear or may be based on by-catches from trawl or dredge surveys for other species such as scallops. The WG agreed that a review of current information was a priority area. A summary of approaches trialled in Ireland was presented and the WG agreed to include this subject in next year's ToRs.

2.5.2.2 Ireland

A number of methods utilised successfully elsewhere were assessed for their application to brown crab fisheries in the NW of Ireland. Directed larvae surveys using a dedicated research vessel were relatively expensive, required a large amount of post-survey processing and failed to fully sample regional hot-spots of abundance. All larvae stages were sampled by using three net types, but late stage larvae displayed diurnal vertical movement patterns that may render some nets ineffective at certain periods of the day. Inshore sampling for late stage larvae was only possible in daylight hours when few individuals would be available to nets, and further work would require the establishment of fixed samplers that could be deployed throughout the day-night cycle. Resources would need to be allocated to annual surveys to ensure continuity using this method, and this is unlikely in the medium term, but obtaining samples/data from other surveys that may have effectively sampled in areas where abundance 'hot spots' occur could be the way forward. Cost-benefit could be achieved if samples for other species could be simultaneously collected and processed.

Late-stage larvae and early benthic phase collectors were not suitable for the very exposed conditions that occur in locations where brown crab fisheries exist. Equipment was regularly damaged and/or swept away by strong currents.

SCUBA diver suction sampling yielded quantitative samples of some habitats that contained early benthic phase individuals, but many other potential areas could not be dived due to exposed aspect and strong tides. Diving was a relatively expensive form of sampling for the low number of areas/samples that could be collected each day.

Scientific observation of commercial fishing and/or targeted fishing from commercial vessels afforded the best value for money in terms of the area that could be covered and reduced post-processing time. Pre-recruits were more common in shallower areas that commercial vessels tended to avoid due to the low number of market sized individuals. Although it was possible to develop probability-based seabed maps for several important inshore fishing areas, it was difficult to define any between-habitat variation in abundance of pre-recruits. This is likely to have been due to changes in catchability and factors affecting the sphere of influence of fishing pots. As industry was directly involved in these surveys, the need for robust assessment and management was highlighted to local stakeholders. There is a lower likelihood of decoupling in the relationship between sub-legal sized crabs 1-2 years/moults from recruitment to the fishery and future additions to the stock than with the other methods trialled. Commercial pots are effective for sampling individuals >85 and <140 carapace width, but it is not possible to isolate individual cohorts. Well designed targeted surveys on nursery ground by commercial vessels using small mesh pots are likely to be the most potentially useful methodology trialled to date. As there is little current need to predict variation in recruitment more than several years in advance, these commercially orientated surveys may be considered the best route forward to developing predictive indices until other methods that allow robust, longer range forecasts are evolved. Further effort to refine and standardise targeted surveys of nursery habitats may therefore be warranted.

2.6 ToR f: Review information on the incidence/prevalence of disease in crab fisheries and review the extent to which bitter crab disease might affect recruitment

2.6.1 Recent Developments in the Crustacean Disease World

Grant Stentiford (European Community Reference Laboratory for Crustacean Diseases, UK) described a new piece of European legislation (EC Directive 2006/88) in which three crustacean viral diseases (causing White Spot Disease, Yellowhead Disease and Taura Syndrome) have recently been listed. The new listing of these diseases essentially dictates that EU Member States National Reference Laboratories (NRLs) are required to investigate mortalities of 'susceptible species' for the presence of the listed pathogens and on discovery, to report these to the appropriate Competent Authority for onwards reporting to the European Commission and (where appropriate) the Office International Epizootique (OIE). Discovery of a listed pathogen within a Member State would affect the disease status of that State (or zone thereof) and this may affect where live animals (and products thereof) can be moved to and from. More information on the Directive and associated issues can be obtained from the website of the Community Reference Laboratory for Crustacean Diseases (www.crustaceancrl.eu). Discussions highlighted the susceptibility of several European crustacean species (including *Carcinus maenas*, *Cancer pagurus*, *Nephrops norvegicus* and *Homarus gammarus*) to White Spot Disease.

2.6.2 Disease Survey of Juvenile Edible Crabs (*Cancer pagurus*)

A year-long survey was carried out in the English Channel, UK on the pathogens and parasites of juvenile crabs (Stentiford, 2008). The study on juvenile crabs highlighted a number of pathogens from juveniles that were not known to occur in adult crabs including a novel haplosporidian parasite, and a virus infection termed CpBV. The haplosporidian infection was reported as being particularly interesting given the high monthly prevalence of this disease in shoreline collected juveniles (up to 80%). The discussion focussed on the relative lack of information on diseases of our most important commercial species and in particular the effect of diseases in younger cohorts on their survivability and their recruitment to the fishery. An understanding of this issue (i.e. cohort success) should be a focus of future research and should be aligned with any moves to assess stock structure of edible crabs. Similar principles could equally be applied to other exploited species, particularly where juvenile and adult specimens are available for study from similar geographic locations. This information will be useful in relation to any move to develop size structured models that look at transition from one size class to the next and the probability that this will happen.

A current crab tagging study being carried out by Cefas in the English Channel is also being used to examine the disease status of crabs. The sampling has now been completed and over 2000 blood samples have been obtained from crabs tagged and released in the mid-Channel off Dartmouth, Devon. The samples (time=0) will be analysed for the presence of the parasite *Hematodinium* and will give the first indication of prevalence (%) of this important pathogen in the offshore fishery. As recaptures occur, it will be possible to calculate the potential for movement of diseased animals vs. non-diseased animals and the relative survival of infected vs. non-infected animals over time. The data will be utilised to assess the effect of this disease on mortality in Channel crabs. Samples have now been returned to the laboratory and will be analysed prior to WGCRAB 2010.

2.6.3 Ireland

A programme to assess the intensity and prevalence of *Hematodinium* in *Cancer pagurus* in Irish waters has recently been published (Ní Chualáin *et al*., 2009). Prevalence was much higher in smaller than larger animals and varied seasonally, making it unlikely that it would be possible to set a prevalence threshold at which management measures could be implemented. Notwithstanding catchability and sampling bias issues, *Hematodinium* can be found at up to 60% prevalence and may well therefore affect cohort size. There is a particular high incidence in smaller animals which do not recover.

3 Terms of reference, dates and venue for the next meeting

Crab species represent some of the most valuable fisheries within the ICES area, and fishing effort has been increasing in most of these fisheries in recent years requiring robust assessment of the status of stocks and appropriate management advice. In 2007 the WG agreed that its long term aim should be to provide an assessment of the status of crab stocks within the ICES area and, if necessary, provide management advice. At present there is little coordination and oversight of national monitoring and assessment programmes, and the WG agreed that it should now meet annually with Terms of Reference that move towards the long term aim of provision of advice on the status of crab stocks. Over the last 2 years the WG has been reviewing the definition of management units for crab stocks, long term trends in fisheries statistics, stock assessment methodology for crabs and the biological parameters underlying those stock assessments. There remains much still to be undertaken before robust evaluation of the various national monitoring and assessment programmes can be completed, and the WG is only just beginning to consider international assessment of stocks fished by more than one country. In 2009 the WG began collation of data from the various national programmes for the Western English Channel stock of *Cancer pagurus* that is exploited by two or more Member States, and this process will continue in 2010 for both this stock and the Malin stock of *Cancer pagurus*, recognising that much will be required outside the duration of the WG meeting. In 2009 the WG reviewed data available on growth rates of exploited crab species, and in 2010 will continue its review of biological data by considering data on the reproductive cycle and maturity and potential sources of pre-recruit indices.

WGCRAB terms of reference for the next meeting

The **Working Group on the Biology and Life History of Crabs** [WGCRAB] (Chair: Julian Addison, UK) will meet in Galway, Ireland, on 20–23 April 2010 to:

a) Compile data on landings, discards, effort and catch rates (CPUE) and provide standardised CPUE, size frequency and research survey data for the important crab fisheries in the ICES area

b) Collate and evaluate all fisheries data from the various national programmes for the Western Channel and Malin *Cancer pagurus* stocks

c) Evaluate national assessments of the status of crab stocks, and identify gaps in assessment programmes

d) Review information on crab larvae distribution and hydrography in relation to current definitions of stock structure / management units for crab stocks

e) Identify potential sources of pre-recruit indices for crab species from both directed programmes and through surveys designed for other purposes e.g. beam trawl and scallop surveys.

f) Review data on reproductive cycle and maturity and other biological information for crabs that is required for providing standardised indices and for analytical assessments

g) Review information on the incidence/prevalence of disease in crab fisheries and review the extent to which bitter crab disease might affect recruitment.

WGCRAB will report by 30 May 2010 (via SSGEF) for the attention of SCICOM

4 References

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

Anon. 2005. Shetland Shellfish Stock Assessment 2005. Fisheries Section, NAFC Report. 51 pp.

Bennett, D.B. 1974. Growth of the edible crab (*Cancer pagurus* L.) off southwest England. J. Mar Biol. Ass. U.K. **54**:803-23.

Bertalanffy, L. von. 1938. A quantitative theory of organic growth (inquiries on growth laws. II) Hum. Biol. **10**:181-213.

Dawe, E.G., Hoenig, J.M., Xu, X. 1993. Change-in-ratio and index-removal methods for population assessment and their application to snow crab (*Chionoecetes opilio*). Can. J. Fish. Aquat. Sci. **50,** 1467-1476.

Grant, S.M. 2004. Mortality of snow crab discarded in Newfoundland and Labrador's trap fishery: at-sea experiments on the effect of drop height and air exposure duration. Can. Tech. Rep. Fish. Aquat. Sci. no. 2481, 31 pp.

ICES. 2007. Report of the Working Group on the Biology and Life History of Crabs, ICES CM 2007/LRC:09.

Latrouite, D., Morizur, Y. 1988. Observations sur la croissance du tourteau *Cancer pagurus* en Manche et en Golfe de Gascogne. ICES CM 1988/K:34..

Leslie, B. & Shelmerdine, R. 2008. Spatial variability in velvet crab populations: A possible candidate for real time fisheries management. NAFC Maine Centre Report. 40pp

Leslie, B., Laurenson, C., Shelmerdine, R, Riley, D. & Simmons, S. 2008. Shetland Shellfish Stock Assessments 2008. NAFC Marine Centre Report, 94 pp.

McKeown, N. J. and Shaw, P. W. 2008. Spatial and temporal genetic structuring of edible crab populations. Final report of Defra Research Project MF0230, Defra, UK.

Mouat, B., Laurenson, C., Riley, D., Marrs, S. & Henderson, S. 2006. Shetland Shellfish Stock Assessments 2006. NAFC Marine Centre Report. 68 pp.

Ní Chualáin, C., Hayes, M., Allen, B., Robinson, M. 2009. *Hematodinium sp*. in Irish *Cancer pagurus* fisheries: infection intensity as a potential fisheries management tool. Dis. Aquat. Org. **83**:59-66.

Open access: http://www.int-res.com/abstracts/dao/v83/n1/p59-66/

Nilssen, E.M. and Sundet, J.H. 2006. The introduced species red king crab (*Paralithodes camtschaticus*) in the Barents Sea. II. Growth increments and moulting probability. Fish. Res. 82: 319-326.

Puebla, O, Sévigny, J-M, Sainte-Marie, B., Brêthes, J-C, Burmeister, A., Dawe, E. and Moriyasu, M. 2008. Population genetic structure of the snow crab (*Chionoecetes opilio*) at the Northwest Atlantic scale. Can. J. Fish. Aquat. Sci., 65: 425-436.

Sparre, P. & Venema, S.C. 1998. Introduction to Tropical Fish Stock Assessment - Part 1: Manual. FAO Tech. Pap. 306/1. Rev. 2. 632pp. (inc. apps.).

Stentiford, G.D. 2008. Diseases of the European Edible Crab (*Cancer pagurus*): a review. ICES Journal of Marine Science **65**, 1578-1592.

Tallack, S. 2002. The biology and exploitation of three crab species in the Shetland Islands, Scotland: *Cancer pagurus*, *Necora puber* and *Carcinus maenas*. PhD Thesis. NAFC/UHI.

Ungfors, A., McKeown, N. J., Shaw, P. W. and Andre, C. 2009. Lack of spatial genetic variation in the edible crab (*Cancer pagurus*) in the Kattegat–Skagerrak area. ICES Journal of Marine Science, **66:** 462–469.

Zheng, J., Murphy, M.C., Kruse, G.H. 1995. A length-based population model and stock-recruitment relationships for red king crab, *Paralithodes camtschaticus*, in Bristol Bay, Alaska. Can. J. Fish. Aquat. Sci. **52**:1229-1246.

Zheng, J., Kruse, G.H., Murphy, M.C. 1998. A length based approach to estimate population abundance of Tanner crab, *Chionocetes bairdi*, in Bristol Bay, Alaska. In: Jamieson, G.S., Campbell, A. (Eds.), Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. Can. Spec. Publ. Fish. Aquat. Sci. **125:** 97-105.

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Annex 2: WGCRAB Terms of Reference for the next meeting

The **Working Group on the Biology and Life History of Crabs** [WGCRAB] (Chair: Julian Addison, UK) will meet in Galway, Ireland, on 20–23 April 2010 to:

a) Compile data on landings, discards, effort and catch rates (CPUE) and provide standardised CPUE, size frequency and research survey data for the important crab fisheries in the ICES area

b) Collate and evaluate all fisheries data from the various national programmes for the Western Channel and Malin *Cancer pagurus* stocks

c) Evaluate national assessments of the status of crab stocks, and identify gaps in assessment programmes

d) Review information on crab larvae distribution and hydrography in relation to current definitions of stock structure / management units for crab stocks

e) Identify potential sources of pre-recruit indices for crab species from both directed programmes and through surveys designed for other purposes e.g. beam trawl and scallop surveys.

f) Review data on reproductive cycle and maturity and other biological information for crabs that is required for providing standardised indices and for analytical assessments

g) Review information on the incidence/prevalence of disease in crab fisheries and review the extent to which bitter crab disease might affect recruitment.

WGCRAB will report by 30 May 2010 (via SSGEF) for the attention of SCICOM

Priority:	High. The fisheries for crabs are becoming socio-economically more important and trans-national in Europe and Canada with the demise of fin fisheries in some regions. Management of stocks in Europe is usually by technical measures only and there are generally no management instruments to control fishing effort. Knowledge of the population dynamics of these species is also weak. These stocks may be at risk from over-fishing due to the lack of control on fsihng effort, and hence an evaluation of the sustainability of these fisheries is necesasary. The activity of the Group is, therefore, considered to be of high priority in particular if it’s activity can move towards resource assessment without losing biological inputs.

Scientific justification and relation to ICES Science Plan:	a), b) and c) The European *Cancer*, *Maja* and *Paralithodes* stocks, some of the Kamchatka crab (*Paralithodes camtschatica)* and the Atlantic Canadian snow crab (*Chionoecetes*) stocks are apparently in a phase of expansion with effort, catch, and CPUE increasing in a number of fisheries, although in some fisheries CPUE may be declining In addition these fisheries are becoming more international in nature and more highly capitalised with the expansion of effort to offshore grounds. [Science Plan- Marine living resource management tools]. d) Although crab stocks are heavily fished and there is no effort control in European fisheries, catch rates appear relatively stable in many areas which may be due to an expansion of fishing grounds. An increased understanding of stock structure will be necessary therefore for the proper management of crab stocks, both nationally and internationally. Information on both the biotic environment including genetics studies and the physical environment are critical in identifying the stock structure of crabs to ensure effective stock management. [Science Plan – Fish life history information in support of EAM]. e) and f) Changes in stock characteristics have important implications for analytical assessments. Biological information is required to provide standardised indices and for use in analytical assessments, and biological characteristics of stocks may change due, for example, to the impact of size selective and single sex fisheries, through by-catch in other fisheries or through the impact of other seabed uses, such as gravel extraction. [Science Plan- Marine living resource management tools]. g) Disease can play an important role in driving the dynamics of crab stocks, and it is important that appropriate monitoring programmes are in place and that the fishing industry is fully aware of how to identify and mitigate against the effects of disease.
Resource requirements:	Existing national programmes provide the main input for discussion. The level of activity and approaches taken in these programmes determine the capacity of the Group to make progress.
Participants:	The Group is normally attended by some 15 members and guests.
Secretariat facilities:	None specific
Financial:	None specific
Linkages to advisory committees:	None
Linkages to other committees or groups:	None
Linkages to other organizations:	None

Annex 3: Working document for ICES WGCRAB

Brown Crab (*Cancer pagurus*) migrations off the Northern Scottish Coast.

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Introduction

Since the early 1900s migrations of commercially exploited decapod crustaceans have been studied using various tagging techniques. These studies in the North Sea coast of England and Scotland suggested that some brown crab (*Cancer pagurus*) moved considerable distances, well in excess of 100km (over periods ranging from 1-2 years) (Williamson, 1900; Meek 1913). The majority of these large scale movements were made by female crabs and were predominantly in a northerly direction, behaviour thought to be related to their reproductive cycle (Bennett 1995). These early experiments were carried out with tags which were attached to the exoskeleton and therefore lost on moulting. However, developments of suture tags which are retained through a moult have enabled study of migrations over longer periods (Mason, 1965, Hancock and Edwards, 1967, Edwards, 1965).

The brown crab fishery off the northern coast of Scotland was for many years a predominantly inshore fishery. However, the last 20 years have seen a rapid expansion of the fishery and a move by some of the larger vessels to grounds further offshore (beyond the 12mile limit). The areas experiencing the most rapid growth are the Sule Bank and the Papa Bank. In addition, in 2004 an area to the north west of Scotland (named the windsock) was closed to mobile gear with meshes over 55mm as part of cod recovery measures. The Sule Bank which is situated within the windsock is now particularly favoured by creel fishermen as their gear are spared the risks of damage or loss from associated from trawling. This marked a move for many vessels from a dispersed offshore fishery to a condensed fishery within the windsock.

Regional assessments of crab stocks around Scotland are currently based on length cohort analyses and use reported landings data and market sampling length frequencies recorded by FRS[1]. Potentially valuable data on fishing effort and catch rate are currently lacking. The assessment areas have been modified to include the offshore fishing grounds, and the most recent assessments indicate levels of exploitation are below Fmax. However given the expansion of the fishery there are concerns about the stocks. In addition, fishermen have questioned whether the inshore and offshore crab stocks to the north west of Scotland are linked or part of the same population, and how fishing in one area may affect the stock in the other.

To addresses this FRS are conducting a tagging study to investigate the movements of crabs captured on inshore and offshore grounds. The study was started in 2008 and is a joint venture, involving the fishing industry funded under the Scottish Industry/Science Partnership (SISP). The aim is to obtain information on migratory and life history patterns of the male and female brown crab to the north west of Scotland. Tagging is undertaken by scientists working on board chartered commercial vessels

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[1] FRS is now part of Marine Scotland

and fishermen are reporting tag returns. Below we report on the study and findings to date.

Materials and Methods

Aquarium Study

Prior to and in parallel with the field study, an aquarium study was set up to investigate tag retention pre and post moult and to establish whether the tagging process had any adverse affect on the crabs. Crabs (28) were caught locally in creels deployed from the FRS research vessel Temora and acclimatised to aquarium conditions for 7 days before being tagged. And fed every 2 days (prawns, squid, small fish, occasionally cod pellets). Some were kept in aquaria inside at an average temperature of 10°C, +/-0.5°C in a recalculated water system. A second batch of 20 crabs was caught and kept in aquaria outside and were subject ambient water temperatures. The water in each system was treated as follows, in the ambient water system water was passed through sand filters and a UV light filter, in the recirculation system the water was passed through a foam fractionator and ozone at low dose rates of 350-400mV, sand filters, fluidized sand towers, UV light filter and bacterial trickle filters. Changes in behaviour and/or death following tagging were recorded. Different locations were also tried for insertion of the tags.

Field study

Crabs were caught using baited creels deployed by commercial fishermen on both the offshore (‘windsock’) and inshore grounds (Figure A). There have been four charters to date. The first was and offshore charter of 5 days in August 2008, the second was carried out inshore in November 2008 over 3 days, in February 2009 a third charter was carried out inshore with the final charter taking place in March 2009 offshore.

All crabs that came up in the first few creels on a string were retained and stored in a bin prior to tagging once this was full tagging commenced. If there was time, and sufficient catch a second bin was filled from the same string, removing any selection bias from the commercial fisherman for condition, size or sex. Strings were hauled from depths of 90–150m.

Crabs were tagged using high visibility T-bar tags from Floy Tag consisting of a monofilament covered in vinyl tubing; these are individually numbered and have details of the information to be recorded on recapture and the web address where tag return information could be found. The tags were inserted using a Mark II long pistol gun also provided by Floy Tag. Once the measurements and sex of the crab had been recorded, a small hole was bored into the epimeral line or line of separation on the carapace with a modified small flat headed screw driver, following this the tagging gun was inserted through this hole and the tag inserted in to the newly forming shell underneath. A small amount of vasoline was then smeared over the bore hole to help seal the crab to aid healing. A coloured cable tie was then tied round one of the chelae. The sex, carapace width (measured to the nearest millimetre below); tag number and whether chelae had been cable tied and the location of capture and release for each crab were recorded.

Individuals less than 120 mm CL were not tagged as smaller animals had been found to be compromised in the aquarium studies and died shortly after tagging. Any white or soft crabs were also discarded as the tag would not be inserted into flesh in these instances. To date a total of 7491 crabs tagged have been tagged, 4216 offshore and 3275 inshore.

Tag returns

Fishermen have been asked to return information on recaptures, this to include the tag number, sex and size of crab date and recapture location. They were also asked where possible to return the crabs to the sea and take note of this re-release location. Various methods, including posters and articles in the fishing press have been used to increase awareness of the tagging programme. For the return of valid information, fishermen's names are being entered in to a prize draw.

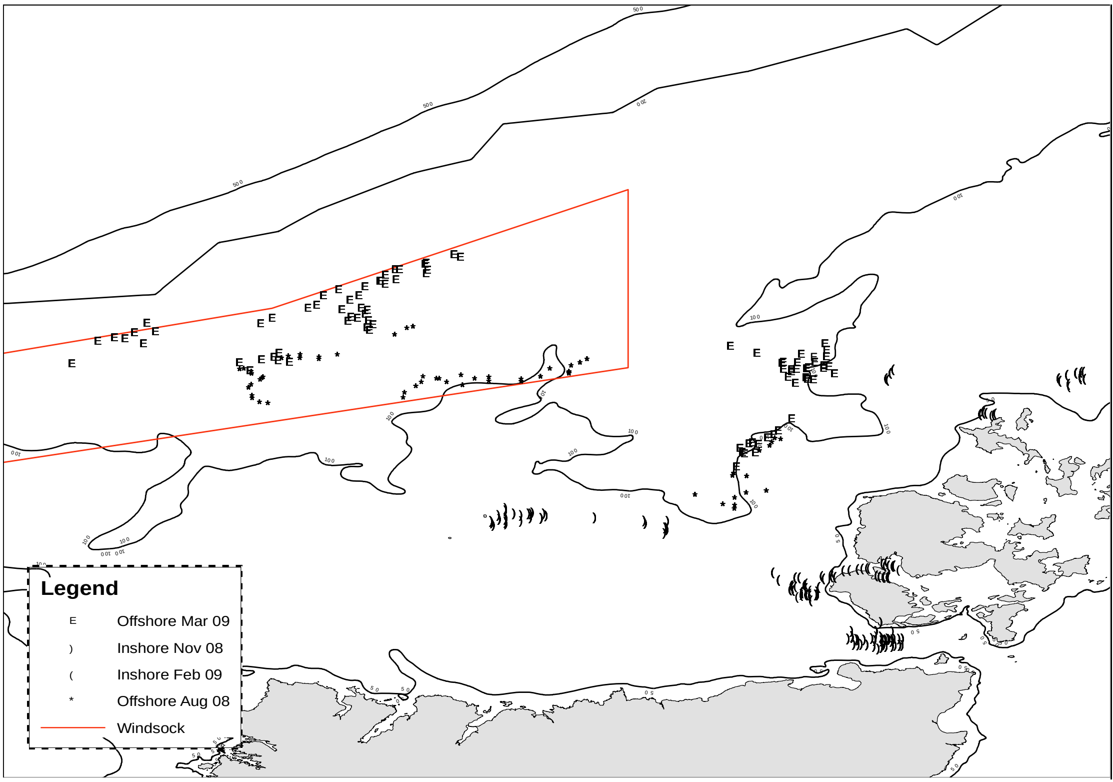

Figure A. Release sites of tagged crabs.

Results

The details of crab movements, inferred from tag release sites and tag returns, are given in Tables 1 and 2.

In the offshore release area, 1.2% of the females and 1.6% of the males released have been recaptured (39 female and 9 male verified recaptures). Just over 23% of females recaptured in the offshore release area had moved greater than 10 km whereas just over 44% of males had moved more than this distance. Data for tag numbers 2802, 2821 and 2835 suggest extensive migrations. Confirmation of recapture locations is being sought before data are included in any analyses.

In the inshore release area 0.8% of the females and 0.2% of the males released have been recaptured (5 female and 2 male verified recaptures). Only 2 recaptured crabs had moved more than 10 km from their release site, one female and one male.

Table 1. Distance between release and recapture locations for crabs tagged inshore.

Tag No.	Sex	Size (mm)	Tag Colour	Distance Travelled (km)	Bearing	Days at Liberty
3314	M	180	Yellow	18.76	W, NW	81
70	M	135	Yellow	2.23	E,NE	2
3915	F	168	Yellow	20.13	SW	52
3881	F	148	Yellow	8.29	NW	56
3297	F	155	Yellow	8.17	NW	27
3870	F	148	Blue	6.54	NW	38
4229	F	160	Blue	5.2	N, NE	96

Table 2. Distance between release and recapture locations for crabs tagged offshore.

Tag No.	Sex	Size (mm)	Tag Colour	Distance Travelled (km)	Bearing	Days at Liberty
3303	M	191	Yellow	0.37	SW	22
4892	M	166	Yellow	4.83	S	19
1743	M	129	Blue	1.19	S	4
2898	M	150	Blue	0.96	SW	3
2026	M	168	Yellow	2.46	SW	4
1833	M	182	Blue	52.27	SE	38
2821	M	160	Yellow	25.97	NW	6
2835	M	152	Yellow	25.97	NW	6
2802	M	182	Yellow	26.68	NW	6
3924	F	150	Yellow	1.19	NW	22
4262	F	172	Yellow	1.22	W,NW	20
4256	F	175	Yellow	1.22	W,NW	20
4919	F	195	Yellow	1.74	SE	19
2576	F	195	Blue	0.66	SW	7
1172	F	155	Blue	1.26	N	7
1129	F	158	Blue	1.26	N	7
2630	F	194	Yellow	4.18	SE	21
1072	F	172	Blue	1.26	N	6
3455	F	177	Yellow	6.33	W,SW	22
1748	F	162	Blue	1.19	S	4
4333	F	181	Yellow	6.32	SE	20
1852	F	148	Blue	2.41	SW	7
1639	F	176	Blue	1.09	SE	3
3417	F	172	Yellow	3.19	SW	7

Tag No.	Sex	Size (mm)	Tag Colour	Distance Travelled (km)	Bearing	Days at Liberty
2936	F	170	Yellow	2.76	SW	6
2019	F	170	Yellow	2.46	SW	4
1193	F	151	Blue	2.02	SE	3
1528	F	168	Blue	2.72	SE	4
1627	F	155	Blue	2.72	SE	4
2964	F	148	Blue	2.05	W,SW	3
1349	F	195	Blue	22.18	E,NE	31
1346	F	160	Blue	22.18	E,NE	31
1384	F	180	Blue	22.18	E,NE	31
1392	F	186	Blue	22.69	E,NE	31
1544	F	163	Blue	2.72	SE	3
1573	F	159	Blue	2.72	SE	3
1572	F	145	Blue	2.72	SE	3
1569	F	150	Blue	2.72	SE	3
1581	F	155	Blue	6.59	S	7
1279	F	189	Blue	10.11	SE	38
2706	F	136	Blue	9.47	N	8
1542	F	154	Blue	7.09	S	6
1566	F	175	Blue	7.09	S	6
1747	F	178	Blue	47.39	SE	38
1326	F	179	Blue	51.68	SE	38
1622	F	160	Blue	61.72	SE	44
1096	F	150	Blue	61.24	SE	43
3212	F	162	Yellow	0.13	S,SW	3

Inshore

There have been very few returns inshore to date. Those which have been returned indicate movements of between 0.01–1.37km/day along the coast of Orkney. The data on size and distance between tag and recapture location are summarised in Figures 1 and 2, suggested no marked differences between the sexes. The sex ration was evenly split between males and females with 52% females to 48% males.

Length frequency distributions of inshore tagged crabs can be found in Appendix 1.

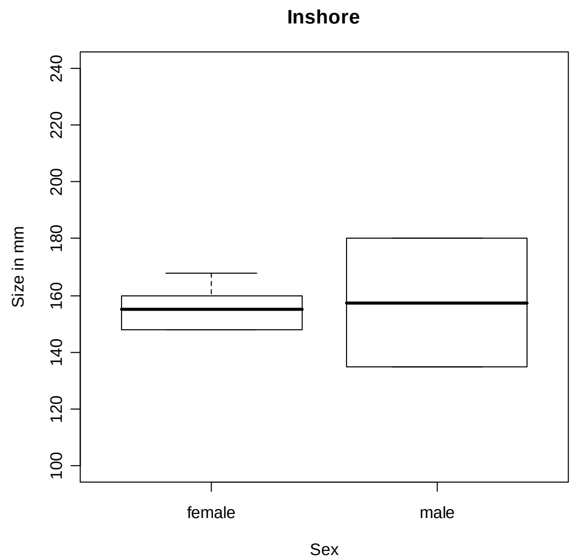

Figure 1. Box plot of carapace width for recaptured inshore tagged crabs (n = 5 for females and 2 for males).

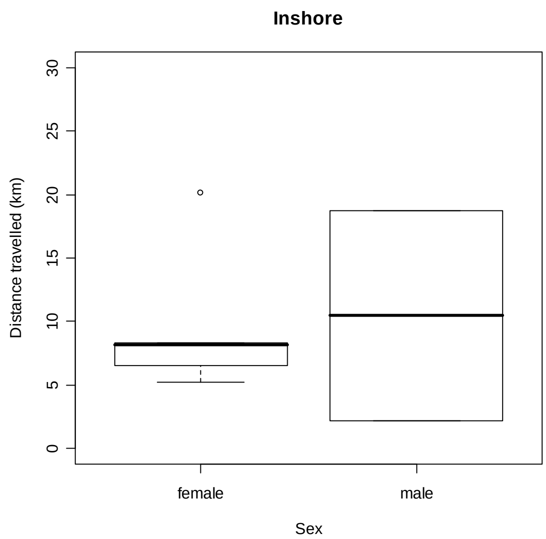

Figure 2. Box plot of distance travelled for recaptured inshore tagged crabs (n = 5 for females and 2 for males).

Offshore

Females predominated in the catches in offshore areas - 90% females to 10% males on the first trip and 84% females to16% males on the second trip. The two trips were carried out on different grounds and at different times of the year but the sex ratio of crabs caught were similar.

The distances between release and recapture locations were in general greater for females than for males, with the majority of females travelling over 0.5 km/day.

There was no significance between the mean size of males and females recaptured or the distance travelled between sexes (Figures 3 and 4). There was little evidence of any relationship between size and distance travelled in either males or females (Figure 5).

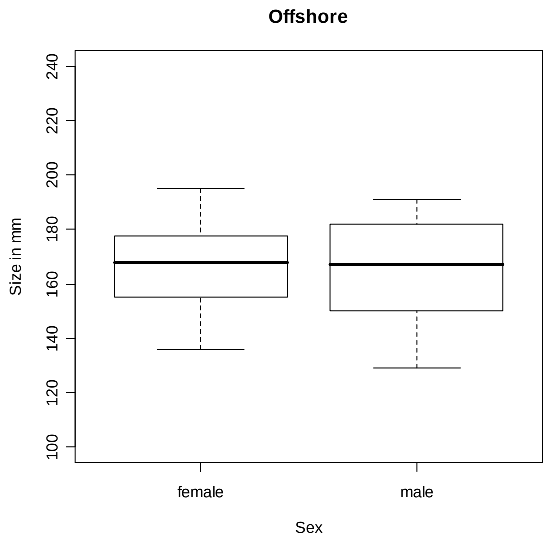

Figure 3. Box plot of carapace width for recaptured offshore tagged crabs (n = 39 for females and 6 for males).

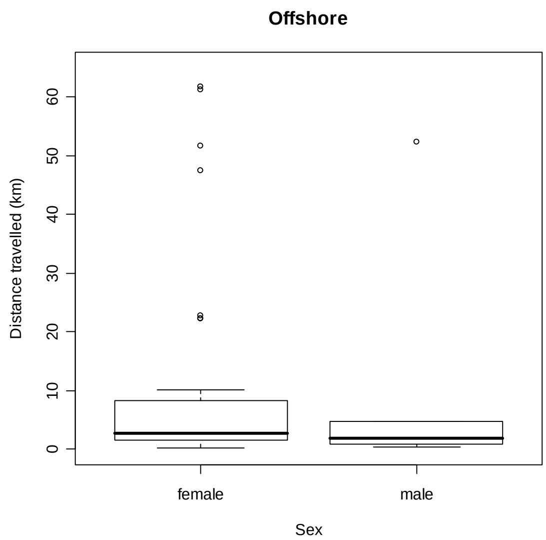

Figure 4. Box plot of distance travelled for recaptured offshore tagged crabs (n = 39 for females and 6 for males).

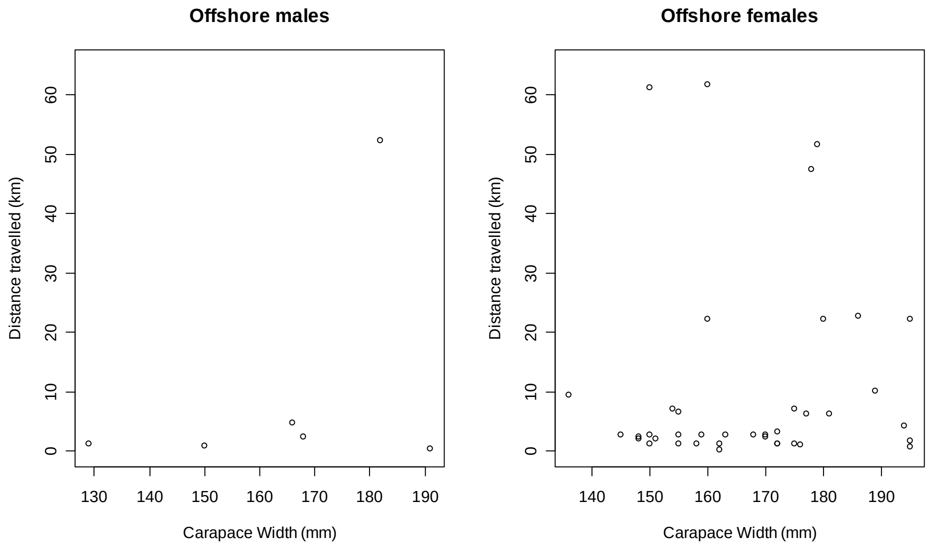

Figure 5. Scatter plots of distance travelled and carapace width for recaptured males and females.

Length frequency distributions for crabs tagged offshore can be found in Appendix 1.

The majority (71.8%) of females released offshore between (August 2008 and March 2009) appear to have moved in a southerly/south easterly bearing, from the windsock towards inshore grounds along the north coast of Scotland and western coast of Orkney (Figure 6).

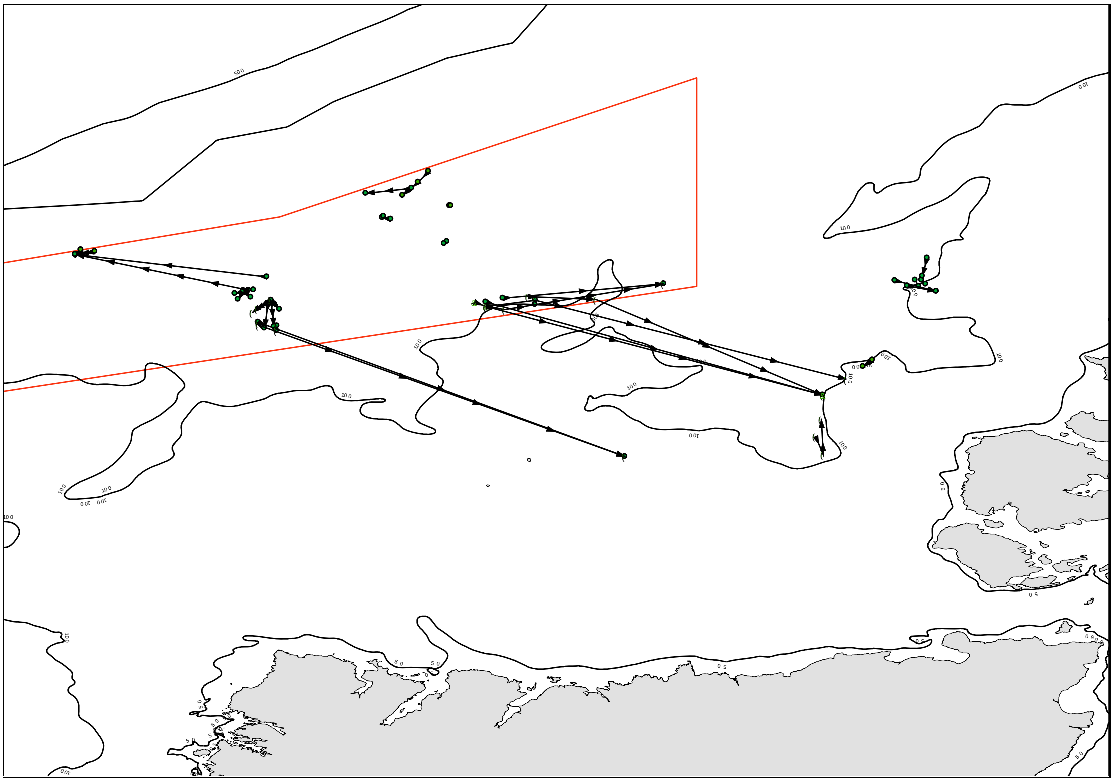

Figure 6. Plot of tracks covered by offshore tagged crabs.

Discussion

The overall return tag rate of 0.87% for this study to date is lower than that reported by other studies (Bennett and Brown, 1983, Diamond and Hankin, 1985, Mistakidis, 1960). This may be a reflection of the size of the study area which is larger than most previous studies. Returns will also be affected by fishing patterns and intensity. There is little fishing between the offshore and inshore grounds and it is possible that tagged crabs may have moved to these areas. However, some tagged crabs have be reported by processors so it also evident that recaptures have not been fully reported, perhaps because the Floy tags are not easily seen. We have attempted to address this attaching cable ties to all animals tagged following the first tagging charter.

Females predominated in the catches offshore. Some of those tagged have been recaptured in shallow water on the west coast of Orkney. These observations support previous findings (Bennett and Brown, 1983, Edwards, 1979) that females migrate from deeper waters to grounds inshore where they moult and mate with resident males. Laboratory studies (Edwards, 1979) indicate that females prefer softer sediments of sand or gravel where they could excavate a hollow in which they lower their abdomen and ensure attachment of the eggs to the pleopods, ground of this type is found further offshore, suggesting that females may migrate offshore to berry.

Males were found in much higher numbers on the inshore grounds during the tagging trips. The limited numbers of males recaptured to date do not appear to have moved from the release sites, possibly indicating that they prefer the rougher ground found there. However, males were also found offshore and these tended to be larger than those inshore. Our findings are similar to those of Bennett and Brown (1983) for males crabs tagged offshore (>18km) in the English Channel. They suggested that larger males were either nomadic or that recaptures were a manifestation of the concentration of fishing effort. They also suggested that movements by the larger males were related to reproduction, with the larger males seeking suitably-sized females for mating.

Overall our findings to date are consistent with movements patterns identified in previous studies and there is anecdotal support from local fishermen in the north west of Scotland that suggests migration takes place between the heavily targeted fishing grounds offshore and the inshore grounds of Orkney. In addition, some vessels which fish in the windsock have reported large catches of crab on the shelf edge at depths of over 200 m, to the north of Sule. Thus, it is also possible that the crabs caught in the windsock are migrating from deeper water and encountering the fishing traps as they traverse the ground.

The study continues. We are currently awaiting recapture details from several vessels fishing on inshore grounds. Further work is planned for 2009/2010 with a further 4 trips planned, 2 offshore and 2 inshore trips, giving further opportunity for collection of more data on movements and stock characteristics.

References

Bennett, D.B. 1973. The effect of limb loss and regeneration on the growth of the edible crab, *Cancer pagurus*, L. J. Exp. Mar. Biol. Ecol., Vol 13, pp. 45-53.

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

Bennett, D, B., and Brown, C. G. 1976. The crab fishery of south west England. M.A.F.F., Lowestoft. Laboratory leaflet No. 33.

Bennett, D, B., and Brown, C. G. 1983. Crab (*Cancer pagurus*) migrations in the English Channel. J. Mar. Boil. Ass. Uk, 63: 371-398.

Diamond, N., and Hankin, D.G. 1985. Movements of the adult female Dungeness crabs (*Cancer magister*) in northern California based on tag recoveries. Can. J. Fish. Aquat. Sci. 42: 919-926.

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

Edwards, E. 1979. The edible crab and its fishery in British waters. Fishing News Books Ltd., Farnham, Surrey, England.

Hancock, D.A. and Edwards, E. 1967. Estimation of annual growth in the edible crab (*Cancer pagurus* L.). Journal du conseil, 31: 246-264.

Meek, A. 1913. The migrations of crabs. Report of the dove Marine Laboratory, Cullercouts, Northumberland, 2: 13-20.

Mistakidis, M.N. 1959. Preliminary data on the increase in size on moulting of the edible crab, *Cancer pagurus*. ICES shellfish committee No. 52.

Mistakidis, M.N. 1960. Movements of the edible crab (*Cancer pagurus*) in English waters. ICES shellfish committee No. 88.

Pearson, J. 1908. Cancer (the edible crab). Mem. Liverpool. Mar. Boil. Comm.., No. 16. 263pp.

Smith, D.B. and Jamieson, G.S. 1991. Movement, spatial distribution, and mortality of male and female Dungeness crab *Cancer magister* near Tofino, British Columbia. Fishery Bulletin. 89(1).

Ungfors, A. 2007. Sexual maturity of the edible crab (*Cancer pagurus*) in the Skagerrak and the Kattegat, based on reproduction and morphometric characteristics. ICES Journal of Marine Science, 64: 314-327.

Williamson, H.C., 1900. Contributions to the life history of the edible crab (*Cancer pagurus*, Linn.). Report of the Fishery Board for Scotland 18: 77-143

Appendix 1

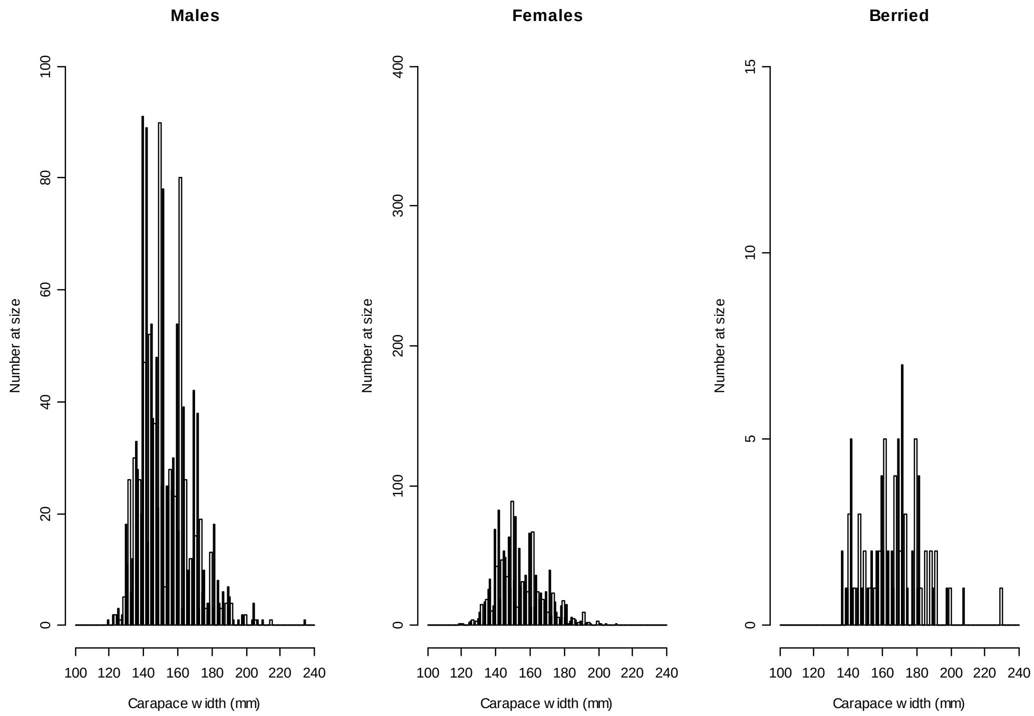

Figure 7. Length frequency distribution of crabs tagged inshore.

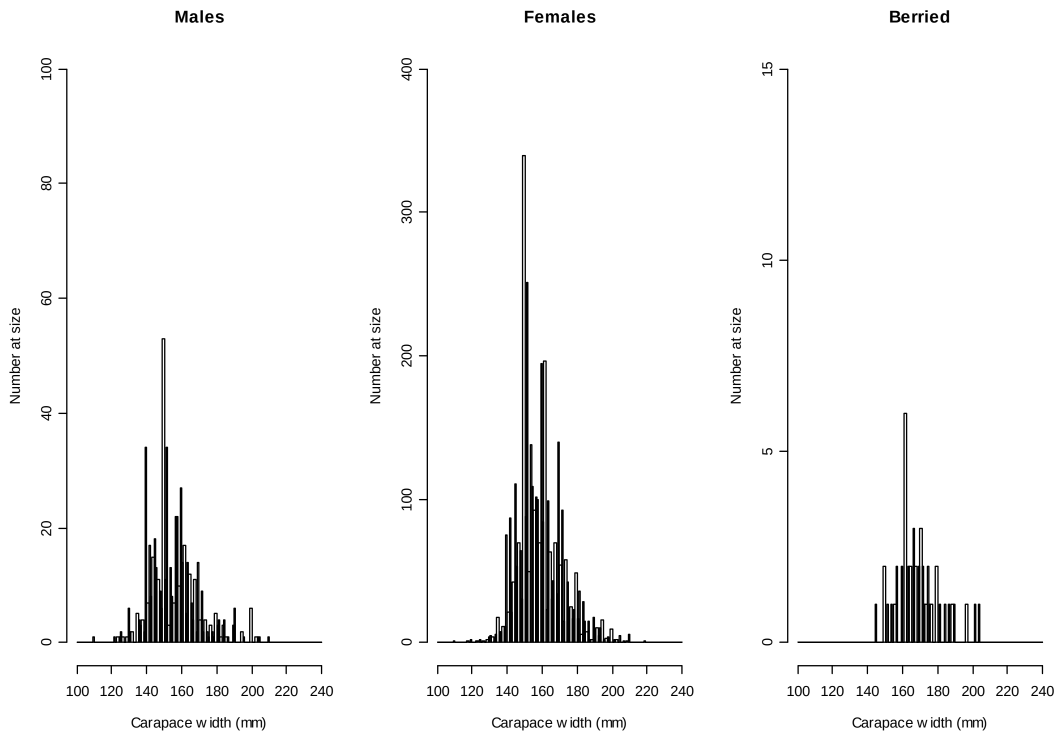

Figure 8. Length frequency distribution of crabs tagged offshore.