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Report of the Working Group on the Biology and Life History of Crabs (WGCRAB)

28 April – 1 May 2008

Brest, France

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Executive summary

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 Working Group (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. 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. 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.

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.

An update was provided on fisheries for brown crab (*Cancer pagurus*) in Ireland, UK, France and Norway, on velvet crabs (*Necora puber*) in UK, on red king crab (*Paralithodes camtschaticus*) in Norway and on snow crab (*Chionoecetes opilio*) in Canada and Greenland. In addition, the WG reviewed the basis of management units for these fisheries in relation to stock structure, and concluded that for most fisheries, management units are based primarily on the geographical distribution of the fishery and not on underlying biology and stock structure. The WG did recommend however that it should move towards a single stock assessment for two brown crab fisheries – the English Channel “stock” fished by vessels from England, France, Belgium and the Channel Islands and the Malin “stock” fished by UK and Irish vessels. The WG recommended that it should meet for any extra day in 2009 to collate fisheries data for these two “stocks”.

The WG carried out a comprehensive review of assessment methods for crab fisheries and the associated data requirements and reviewed the range of biological studies that are ongoing within the various fisheries. The WG agreed that it should also systematically review the biological parameters, such as growth, natural mortality, length-weight, migration, and maturity and fecundity that are required for assessments, and their spatial variability. The WG agreed that it would start at the 2009 meeting with a review of growth parameters and how they are estimated for the various fisheries. Finally the WG continued its review of diseases in crab fisheries. The challenge with all infectious agents is to gain an understanding of how disease agents regulate populations and at what life history stage.

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, as reported in C.M. 1993/K:3. The Study Group 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*), as reported in C.M. 1996/K:1. 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 Study Group 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 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.

1.2 Terms of Reference

The Working Group on the Biology and Life History of Crabs [WGCRAB] (Chair: Julian Addison, UK) will meet in Brest, France in May 2008 to discuss the following Terms of Reference:

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

b) Compile data on landings, discards, effort and catch rates (CPUE) for the important crab fisheries in the ICES area

c) Provide standardised CPUE, size frequency and research survey data

d) Review and compare assessment methods for crab fisheries and the associated data requirements

e) Review biological information that is required for providing standardised indices and for analytical assessments

f) Assess and report on the effects of disease on crab fisheries, and produce a manual for the fishing industry on *Hematodinium* infection of crabs including bio-security.

1.3 List of participants at the WGCRAB 2008 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 In response to ToR a)

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

The first stage in undertaking a stock assessment is to identify the structure of the stocks in relation to the geographical distribution of the fishery. Once a putative stock structure has been agreed, appropriate management units can be identified. In practice of course, strong evidence on stock structure may not be available and management units may have to be based primarily on the geographical distribution of the fishery. The Working Group reviewed the current management units for crab species exploited in the ICES region, the criteria used to define those management units and considered the utility of biological, hydrographical and genetic information for identifying crab stock structure, and how that information relates to the current management units.

2.1.1 Snow Crab (*Chionoecetes opilio*)

In Canada the snow crab is distributed widely off the coast of Newfoundland, Nova Scotia and New Brunswick. Management units are based on NAFO regions and subregions. There is no strong biological basis for these management units (although management units off Cape Breton are based partially on bottom topography), which reflect the distribution of the fisheries and the communities that fish them and on geographical features. The inshore zones in the bays run headland to headland and offshore areas are based on fishing activity and latitude and longitude. The offshore areas are approximately 8000–9000km^2. Tagging studies suggest very little movement with 90% of crabs recaptured within 16km of release location. However 3–4 % of crabs move significant distances (up to 110 miles) and so there is potential for movement between both inshore and offshore management units. Assessments are undertaken for the inshore and offshore stocks and then the ensuing quotas are split into smaller spatial areas, even though management boundaries may run straight through a major patch in snow crab distribution. Genetics studies suggest possibly one large stock of snow crabs in Canadian waters. In conclusion the boundaries of Canadian snow crab management units are based on a pragmatic approach to local fisheries management rather than biological information about local stock structure.

In Greenland the snow crab fishery occurs on the west coast and the management units consist of six areas of various sizes and are based on geography. Inshore and offshore fisheries are assessed separately because tagging experiments suggest no movement between inshore and offshore, but management areas combine both inshore and offshore fisheries. There is no evidence of any genetic differences between inshore and offshore areas.

Snow crabs have a wide geographical range with fisheries in Norway, Russia, the Bering Sea and Japan. Whilst there is clear delineation of stocks between large geographical areas, e.g. between Greenland and Canada, there is little evidence of differences on the spatial scale of current management units.

2.1.2 King Crab (*Paralithodes camschaticus*)

There are currently two management units for the king crab - the Norway zone and the Russia zone. These units were jointly managed from 1994 until 2002 after which the Norwegian zone was managed separately because of different management strategies in the two zones. However there is no strong biological information that supports the existence of separate stocks in the two zones. In Norway larvae of the king crab drift westwards along the north coast of Norway, which is counter to the migratory pathway, suggesting a single stock.

2.1.3 Brown (edible) crab (*Cancer pagurus*)

2.1.3.1 UK

England and Wales

There are two large stock units of brown crab - the English Channel / Western Approaches / Celtic Sea and the North Sea. However it is not clear whether there is any stock structure within those two large areas, for example between the eastern and western Channel, or between the central and southern North Sea. Cefas scientists have further divided these two large stock units into 6 management areas for which separate assessments are undertaken - Central North Sea, Southern North Sea, Eastern Channel, Western Channel, Celtic Sea and Irish Sea. The criteria for these units are based upon larvae distributions, hydrography, and centres of major fishery landings. Genetics studies do not provide any basis for these six sub-divisions, and although based on some biological information, the boundaries have been drawn therefore on a primarily pragmatic basis.

Scotland

The main management units are west coast, east coast and Orkney/Shetland. However little is known about stock structure or whether inshore and offshore fisheries are linked through larvae distribution or movement of adults. Historically landings have been reported on a relatively small scale providing 13 assessment areas, but there is no biological basis to these areas. One assessment area is only a single ICES rectangle, and is obviously therefore only part of a stock. The way in which landings data are reported is being reviewed based on the main fisheries, and whilst it is clear that Orkney and Shetland are obvious "fisheries" which might be managed as a "stock", crabs in these fisheries may still be part of a much wider stock. There are also likely overlaps between the crab fisheries off the south west coast and the Malin fishery exploited by the Irish fleet, and between the east coast fleet and the fisheries exploited by English vessels south of the border between Scotland and England.

The Shetland Islands crab fisheries are a special case within Scotland because they are managed under a Regulating Order which extends out to 6 miles from the coastline. Management of this fishery is therefore based on the geographical limits of the Regulating Order rather than on stock structure.

Isle of Man

Very little is known about the crab fishery around the Isle of Man and currently there are no stock / management units defined for this species. Fishermen's log book data are available and generally aggregated at the level of the west and east coast fishing grounds, and local hydrographic data indicate that such an east/west split may be appropriate for the purposes of management.

Jersey

The management unit represents the extent of the Territorial Sea of Jersey, although together with the French areas of Basse-Normandie and Brittany, the management unit would cover the area set out in the Bay of Granville Treaty. The area is divided into six sub-zones, based on the ICES divisions.

2.1.3.2 France

As with UK *Cancer pagurus* fisheries, there are no defined management units based on known stock structure although three zones (Western Channel, North of Biscay, Celtic Sea) are currently used in a pragmatic approach to assessment and management. However it is clear that French vessels fish the same stock as English and Channel Islands vessels, so it will be necessary for scientists to at least agree on a shared stock and assess the stock accordingly even if ultimately the fisheries are managed separately by the various nations.

2.1.3.3 Ireland

There are two stock/ management units, Northwest and east/south (with links to the western approaches stock). The northwest management unit is split into an inshore (< 12 miles) and offshore (> 12 miles) sector and are assessed and managed on that basis.

2.1.3.4 Norway

The whole coast of Norway is the current management unit for this species. It is subdivided into six zones for reporting purposes based partly on biological grounds with a minimum landing size (MLS) of 130 mm carapace width (CW) in the northern zones with a smaller MLS of 110 mm CW for the slower-growing populations in the southern zones.

2.1.4 Spider Crab (*Maja brachydactyla*)

As was the case with *Cancer pagurus*, boundaries of management units for spider crabs in most European countries are based generally on fisheries rather than biological information. It has been proposed that there is an English Channel stock as well as stock units off Spain, but stock structure for this species is complicated by recent significant changes in geographical distribution of the species due to warmer waters in recent years. Further work is required to identify stock / management units for spider crabs.

2.1.5 Velvet Crab (*Necora puber*)

Management units for velvet crabs in the UK and Ireland are based on the broad geographical distribution of the main fisheries. The only defined stock / management units for this species at present are four zones, all inshore (< 6 miles), in Shetland. These zones are not based on local stock structure, but significant differences in population parameters are observed over very small geographical scales.

2.1.6 General conclusions covering all species

For all species of crab exploited in the ICES area, the fisheries are managed by management units which do not necessarily relate to biological stocks. Most management units are determined on a pragmatic basis with some biological criteria, but based primarily on distribution of the fisheries and geographical features. The basis for fisheries management should be the stock, so there is a need to concentrate on identifying stock structure in order to improve management of these fisheries. We need to know more about the biology of crabs, in particular movement of adult crabs and how they relate to the reproductive cycle and hydrography, and understand more fully larval behaviour in the water column and the settlement process and how these processes are affected by hydrography and temperature. The WG would welcome information on larvae distributions and local hydrography and the likely variation in hydrographic patterns. For example, we need to understand the likelihood of unusual hydrographic patterns in relation to "average" conditions, large scale and localised patterns, and link these temporal variations in hydrographic patterns with the timing of larvae being realised into the plankton.

What little genetic information is available for crab species in the ICES region is not generally used to define fisheries management units. A European study looking at the genetics of the brown crab, *Cancer pagurus*, showed no obvious stock structure at the regional geographical scales at which the fisheries are managed. Nuclear DNA markers show "chaotic patchiness", suggesting an element of low but significant genetic differentiation among localities, but not based on any obvious geographical pattern or related to large scale hydrodynamic features. Mitochondrial DNA markers indicate a more distinct spatial pattern, with an obvious breakpoint at the eastern end of the English Channel (i.e. Eastern English Channel and North Sea populations are different). In general, the English Channel population is distinct from the North Sea, and the samples from Ireland suggest that the western British Isles is more similar genetically to the North Sea than it is to the English Channel, although there are also significant differences among the samples from southeast, southwest and northwest Ireland. There is a suggestion that a "centre of genetic diversity" lies in the northern North Sea (around Shetland-Orkney). These are however preliminary conclusions and more work is required before information on genetic structure of *Cancer pagurus* populations can be incorporated into the definition of management units.

The WG noted that whilst most fisheries management units were based on pragmatism related to the distribution of the fisheries and geographical features, there were clearly some crab fisheries where political boundaries created more than one management unit for what was clearly a single fishery. Whilst it was recognised that it is difficult to manage on the basis of a biological stock, and even if that was possible, there would be a need to avoid local depletions, scientists should at least be able to provide an assessment of a fishery even when political boundaries cross that fishery. The WG agreed to move towards a single stock assessment for two brown crab fisheries – the English Channel "stock" fished by vessels from England, France, Belgium, Channel Islands and possibly Ireland, and the Malin "stock" fished by UK and Irish vessels. The first stage to be undertaken prior to and during next year's WG was to collate data on a stock basis for each of these two geographical areas, and determine whether a single international assessment for the two stocks could be carried out or whether the nature of the different national fisheries requires separate assessments.

2.2 In response to ToRs b) and c)

ToR b) Compile data on landings, discards, effort and catch rates (CPUE) for the important crab fisheries in the ICES area

ToR c) Provide standardised CPUE, size frequency and research survey data

2.2.1 Background and summary of issues raised

The Working Group discussed these two Terms of Reference together and presentations and data were received on fisheries for *Cancer pagurus* in Ireland, UK, France and Norway, on velvet crabs (*Necora puber*) in the UK, on *Paralithodes camtschaticus* in Norway, on snow crab (*Chionoecetes opilio*) in Canada and Greenland, and on *Carcinus maenas* in the UK. 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. At this meeting, the Working Group highlighted a number of issues that arise with the collection and analysis of data and these issues will need to be resolved before data analysis and stocks assessments can be standardised across countries and stocks.

2.2.1.1 Catch and landings per unit effort data

The Working Group recognised three categories of problems encountered with the use of catch per unit effort (CPUE) and landings per unit effort (LPUE) data in stock assessments: poor quality of landings and fishing effort data, lack of standardisation of data across fisheries and interpretation of trends in CPUE/LPUE.

There is a wide variation in the quality of landings and effort data across the various crab fisheries within the ICES area. For the snow crab fisheries in Canada, data on landings and fishing effort were considered to be of very high quality with four separate indices of LPUE providing evidence of changes in stock abundance. In comparison for the *Cancer pagurus* fisheries in Europe, landings data are not always accurately recorded, and in some regions, there is no accurate time series of fishing effort. In the UK, there have been a number of recent changes in regulations in relation to the recording of basic fisheries statistics in brown crab fisheries which has compromised what little time series of data were available, but the recent changes should ensure that high quality data should be available in future years. As a minimum it is necessary to have information on the number of pots in the water, the number of pots hauled each day, and these data should be collected on a daily basis. Good quality LPUE data are available in the UK for a selection of vessels across the whole fleet (Cefas log books) and for all vessels in a localised area (Sea Fisheries Committee permit schemes), but for good quality stock assessments, and if a full effort census of the fishing fleet is required, these data are required from all vessels. Within Europe there is a need to ensure that EU log books are completed fully for the over 10 m fleet, and that permit schemes are in place to cover the under 10m fleet. The Working Group recognised however that for many crab fisheries, there are a vast number of small vessels, and it may be difficult logistically to collect accurate data, especially on fishing effort, from all vessels, and trends in LPUE from "sentinel" or index vessels may be sufficient as an index of stock abundance. Whilst a sample of the key vessels will not give a direct estimate of total effort in the fishery, it is possible to extrapolate from these index vessels to the whole fleet. In future, self-sampling schemes, such as the EU LOT1 project on *Cancer pagurus*, may be the solution to obtaining data from all vessels in a fleet. Even then it is not always obvious how to aggregate LPUE data across vessels and areas as part of a formal stock assessment process.

Ideally the working group would like to make comparison of annual and seasonal trends in LPUE across regions, such as the brown crab fisheries exploited by English, French and Channel Islands vessels. This will aid in assessing the status of stocks across regions and help to interpret whether seasonal patterns are observed across the regions and whether those seasonal patterns are a function of crab biology or the nature of the fishery. However all such time series of LPUE data need to be standardised for temperature, soak time etc. , and that is not currently the case within the European brown crab fisheries.

Even when good quality LPUE data are available and have been standardised, there will always be problems of interpretation because of the nature of the fisheries for crabs. LPUE data are influenced by the behaviour of the target species, and the behaviour of the fishermen who may bait or rig gear differently to target different species or size of crabs to meet current market conditions. For example, LPUE in trap fisheries may be as much a function of catchability as of abundance, as feeding behaviour, temperature, reproductive status and the presence of other animals in the trap may all influence the behaviour of crabs around traps, and hence these influences must be taken into account when interpreting trends in LPUE. A particularly notable example of this problem was presented for *Carcinus maenas* in North Wales. In addition, pots/traps can get saturated at high crab densities and hence no longer be an index of stocks abundance, and subtle changes in distribution of the fishing fleet could mask declines in stock abundance. The other key problem may be seasonal changes in the target fishery. For example in Europe, lobster, crabs, spider crabs and velvet crabs may be caught in the same gear at any time during the year, so for interpretation purposes, it is important to identify the key target species of each fishing operation. Trends in LPUE for other species which are not the key target should be used with great caution. Finally soak time may have a significant effect on catch rates, although this effect may be different for different gear types. In conclusion there is often a "story" behind every point on a time series of LPUE, and it is important that managers are aware of as many of those "stories" as possible.

Many of the problems of interpretation of LPUE data can be reduced by the use of multiple indices as is the current practice in the Canadian snow crab fisheries. In particular a mix of fisheries-dependent data (e.g. from commercial trap data) and fishery–independent data (e.g. from trap surveys or preferably trawl or other surveys) would provide calibration of trends observed in commercial fisheries data, although for some species it may not be possible to sample quantitatively with trawls or other gear.

2.2.1.2 Size frequency data

Size frequency data are collected across a wide range of crab fisheries within the ICES regions. In principle these data provide an index of exploitation rate. Concern has been raised however about the reliability of indices of exploitation based on changes in size frequency distribution. In the North West Irish fishery for *Cancer pagurus*, the size distribution of the catch has remained remarkably constant despite an obvious decline in the stocks. Size distribution analysis is not sensitive enough to detect changes in the fishery if the exploitation is already very high, but the use of length based methods such as length cohort analysis (LCA) can give information on mortality and recruitment rates. However care must be taken in using size distribution data in assessments because size distribution is species and sampling gear dependent, and there may be size-based behavioural interactions occurring around traps which influences the size distribution of the catch, but it can be helpful describing selectivity and in identifying future recruitment. As with LPUE data, it would be helpful if commercial size distribution data could be compared with size distribution data collected from a fishery-independent source.

2.2.1.3 Research surveys

Research surveys are expensive but can be critical to estimating whether commercial fisheries data provide a representative index of the population on the ground. Ideally research surveys should use mobile gear, but whilst this may sample effectively for snow crabs and spider crabs, it would not work well for brown crab because it is impossible to drag mobile gear over key commercial fishing areas which are fished all year. Closed seasons provide an opportunity to get good independent estimates of the stocks. Research surveys are particularly useful for identifying recruitment pulses in pre-recruit size ranges whether through the use of trawls or small-meshed traps. Norway & Russia carry out ecosystem cruises, rather than species-specific surveys – these are more expensive as they require more experts on board. In Norway the surveys use either underwater video survey or trap surveys because it is not possible to use a beam trawl survey due to seabed topography. However there are problems with all types of survey in ensuring that the population is being adequately sampled. The Working Group concluded that it would be instructive to investigate all sources of fishery-independent data for potential indices of crab recruitment and abundance.

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 (<10 m vessels) was presented in last year's report (ICES, 2007). RSLS has led to some delay in reporting of fishing activity data for <10m fleet and the most recent year's data should therefore be considered provisional.

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 >10 m fleet contributed the major part of the landings for the 1990s 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 <10 m fleet than the >10 m 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 <10 m vessels in 2006 is apparent, producing increases in both recorded landings and effort for that fleet.

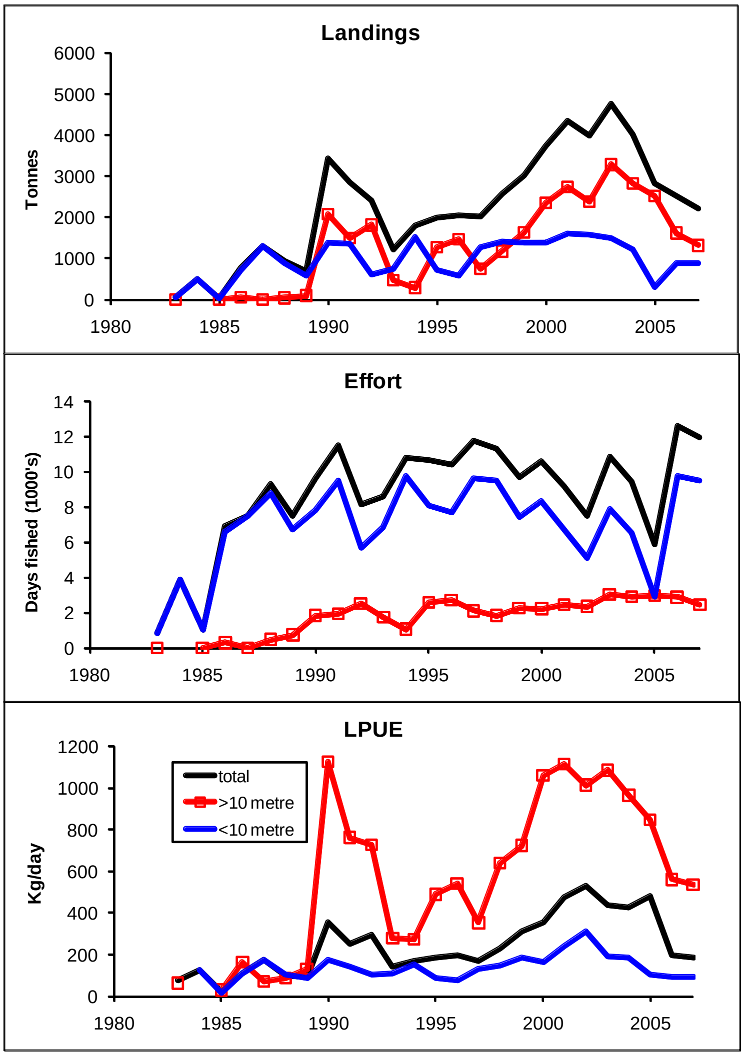

Figure 2.1. Landings, effort and LPUE for the Southern North Sea brown crab (*Cancer pagurus*) fishery.

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 <10 m sector, although there was also a comparable rise in landings by the >10 m 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 >10 m fleet, but a small fall for the <10m fleet. Overall the days fished of the >10 m fleet has remained fairly constant with larger fluctuations in the <10 m fleet where switching of target species is more prevalent. The effect of mandatory returns for the <10 m fleet has had an obvious effect on reported effort from 2006.

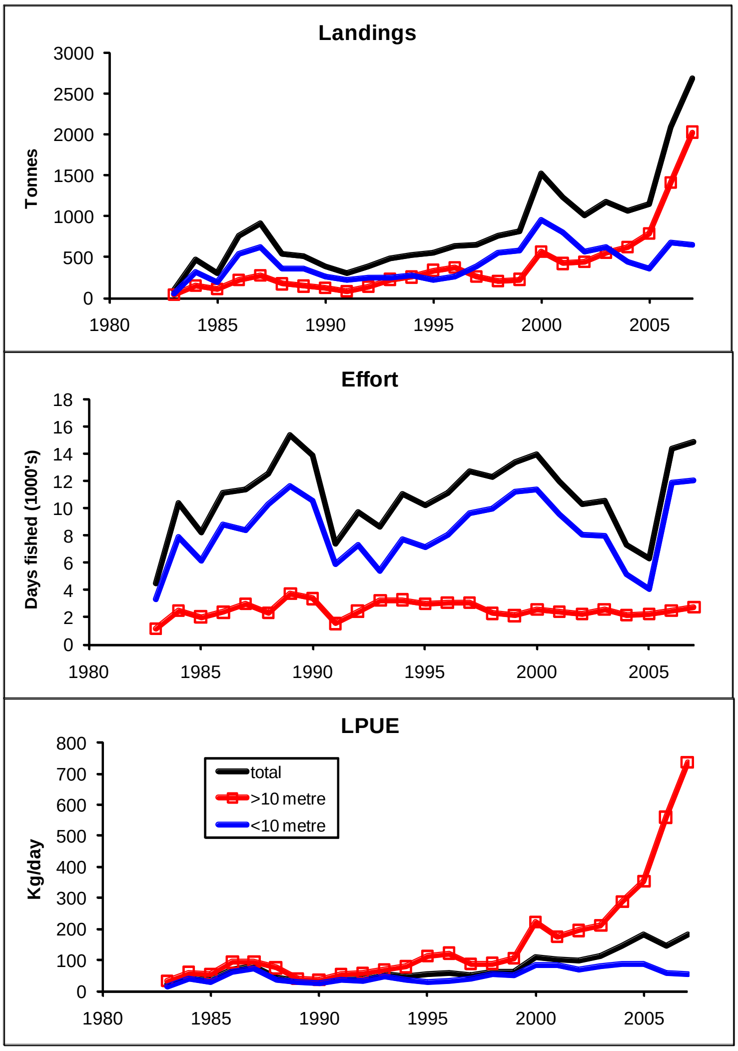

Figure 2.2. Landings, effort and LPUE for the Central North Sea brown crab (*Cancer pagurus*) fishery.

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 <10 m and >10 m 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 >10 m fleet has declined slightly since 2001, although not to the low levels observed in 1998 or the late 1980s. LPUE for the <10 m sector appears to have declined through the late 1990s and early 2000s.

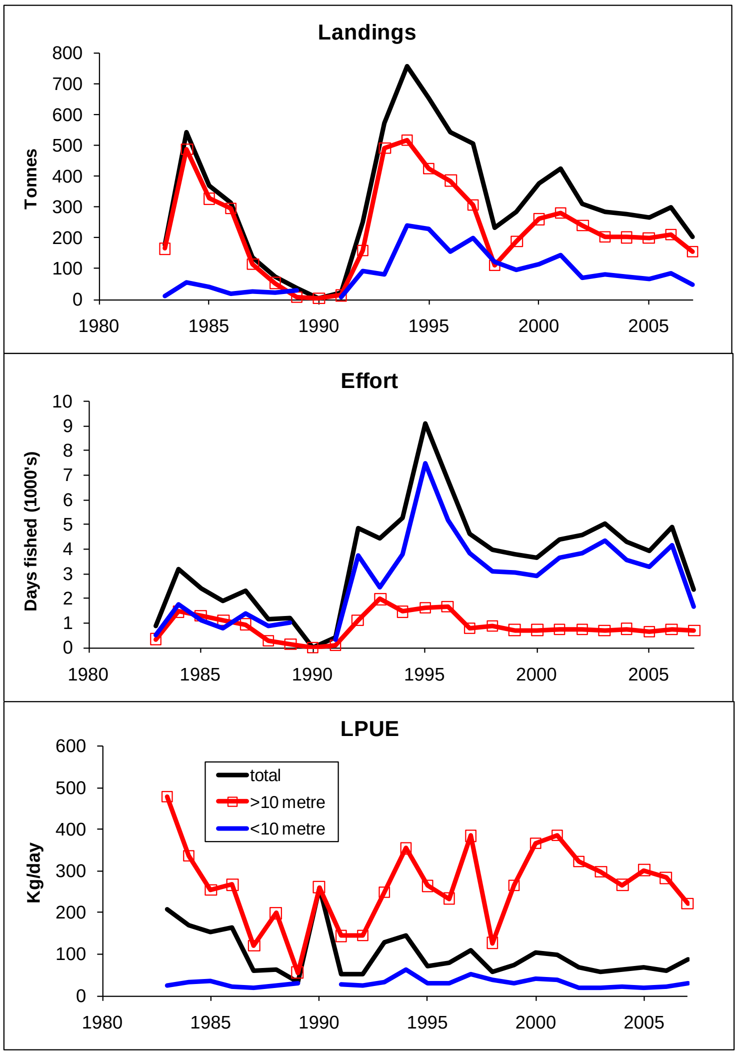

Figure 2.3. Landings, effort and LPUE for the Eastern Channel brown crab (*Cancer pagurus*) fishery.

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 10 000 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 >10 m and <10 m sectors. Since 2006, effort for the <10 m fleet exhibits a five fold increase. The >10 m fleet, which is well represented in this region, exhibits a much higher LPUE than the <10 m 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 <10 m fleet is again evident and has led to the marked drop in total LPUE (combined fleets) in 2006.

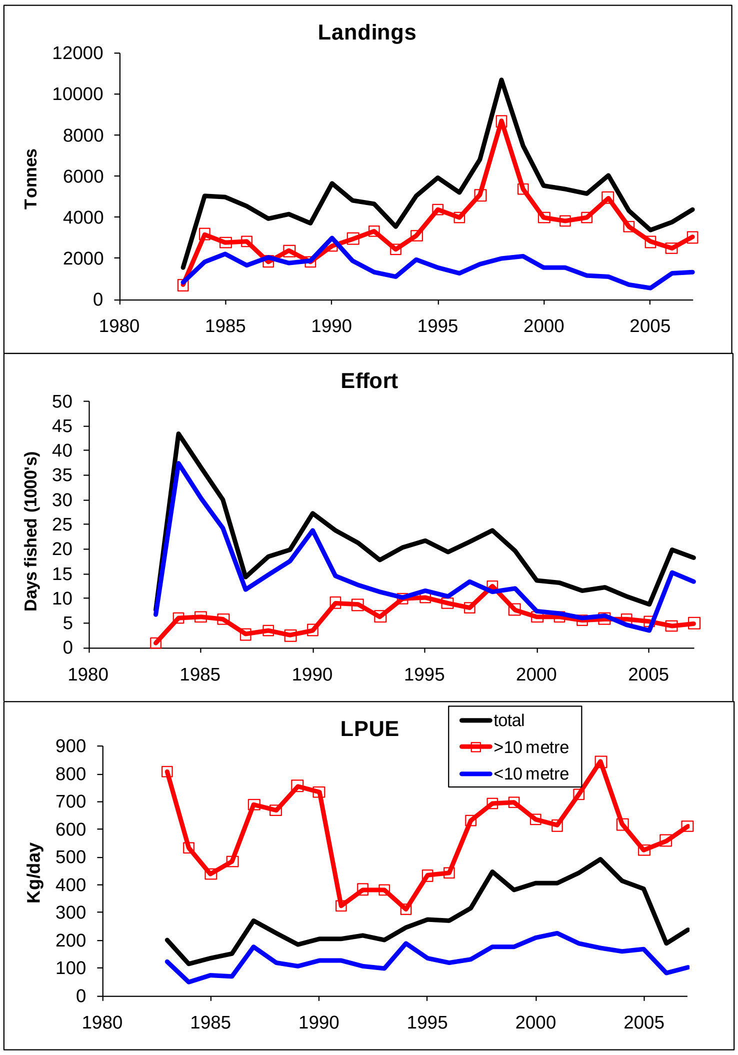

Figure 2.4. Landings, effort and LPUE for the Western Channel brown crab (*Cancer pagurus*) fishery.

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 >10 m fleet (Figure 2.5). LPUE appeared to rise from around 100 kg day^{-1} in 1990 to approx. double that by 2005. However, the <10 m fleet is very strong in this region and there is almost certainly a strong element of under-reporting of <10 m 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.

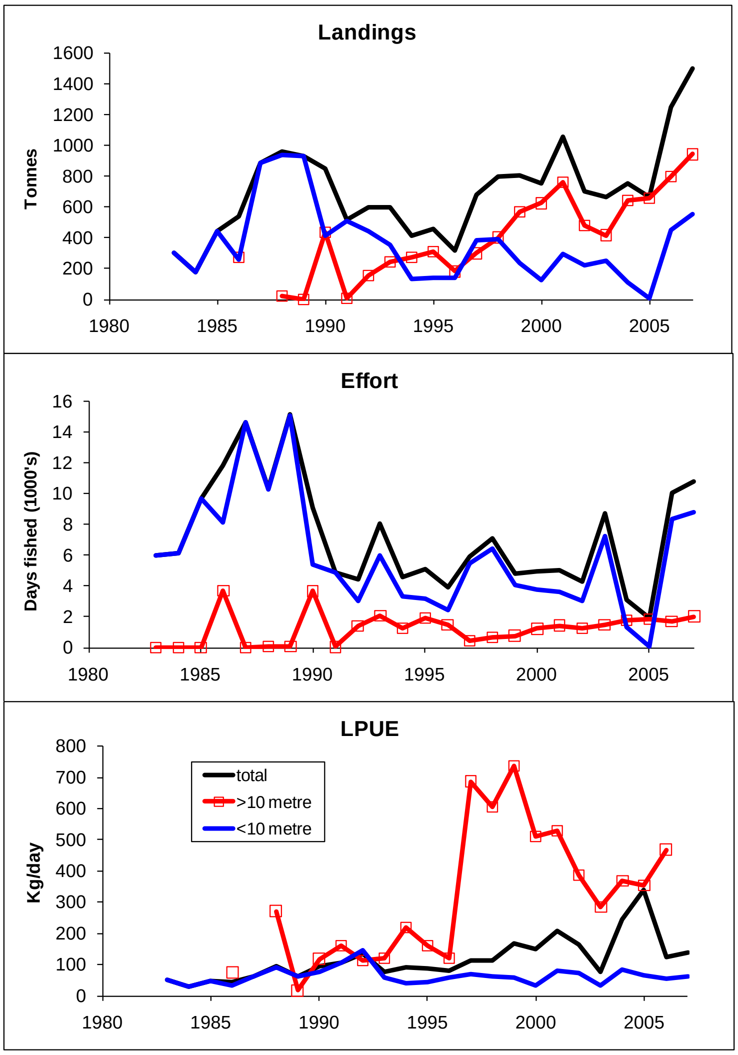

Figure 2.5. Landings, effort and LPUE for the Celtic Sea brown crab (*Cancer pagurus*) fishery.

Irish Sea

Crab landings in this region have been low compared with other areas and are almost exclusively by <10 m 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.

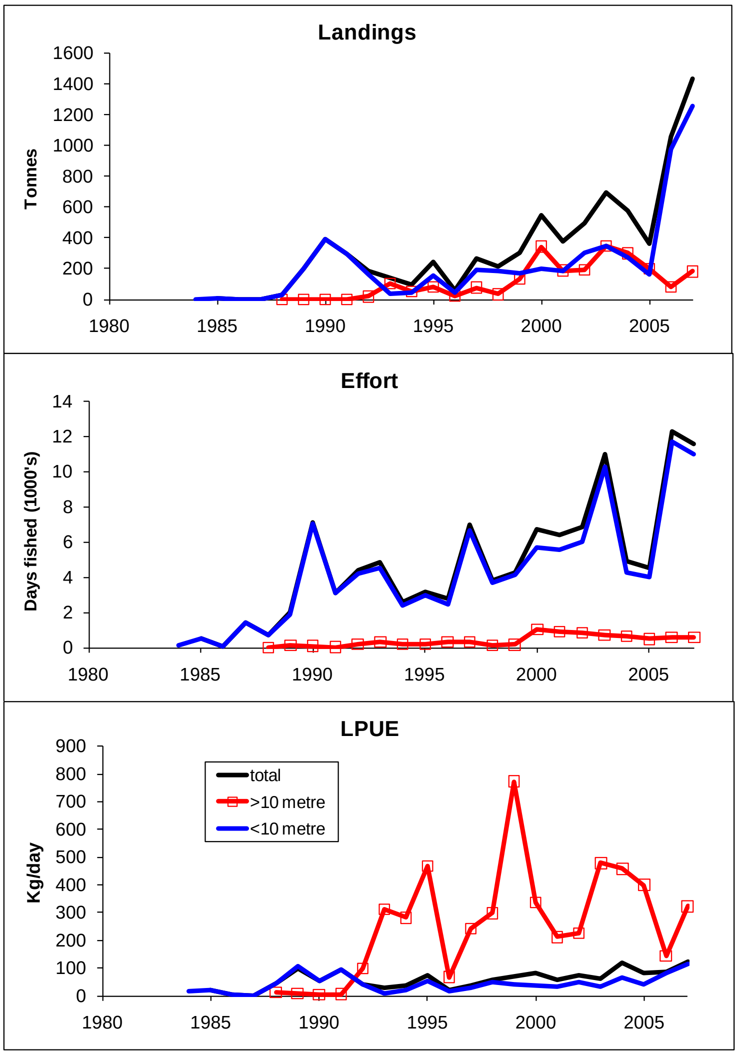

Figure 2.6. Landings, effort and LPUE for the Irish Sea brown crab (*Cancer pagurus*) fishery.

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.

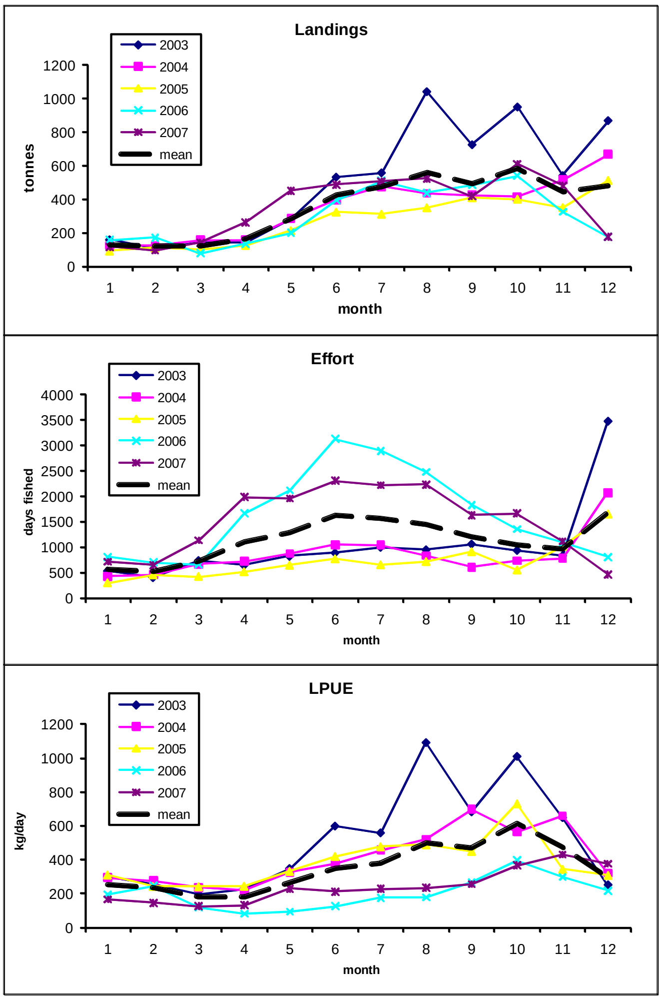

Figure 2.7. Seasonal trends in landings, fishing effort (days fished) and LPUE for the Western Channel brown crab fishery from 2003 to 2007.

2.2.2.2 Scotland

2.2.2.2.1 National data

Over 13 000 tonnes of brown crab were landed in Scotland in 2007, the highest landings on record (Table 2.1). A change in legislation in 2005 requires all landings to be reported and this resulted in significant increases in recorded landings from previous years in some areas. The population structure of brown crab in Scotland is not well understood, although it is likely that populations on the west coast are contiguous with those of the Malin Shelf to the north of Ireland.

For assessment purposes, FRS Marine Laboratory in Aberdeen currently collates landings data by 12 assessment areas (Figure 2.8). The principal fishing areas for brown crab in Scotland are Hebrides, Orkney and the South Minch (Figure 2.9); landings from these areas account for approximately 50% of the national brown crab landings. The fishery in the offshore areas to the north of Scotland, including the Sule, Sulisker and Papa banks, has expanded since the mid to late nineties and now accounts for a further 25 % of the national landings. The South East was the only region to show an overall decreasing trend in landings of brown crab during the past 20 years, although landings have increased in the past few years. The offshore region has a peak in landings in June, but inshore the peak is around October, which may be driven more by the market than seasonality in crab availability. The December peak in landings in the Hebrides is driven by the high demand for Christmas.

Table 2.1. Annual Brown crab landings in 12 Assessment areas in Scotland from 2000–2007.

Area	Year							
	2000	2001	2002	2003	2004	2005	2006	2007
Clyde	31.7	16.0	2.0	7.7	2.8	7.3	61.4	73.8
East	1097.8	855.3	529.1	426.5	369.5	404.9	830.4	884.0
Hebrides	1847.2	1831.4	1613.3	1452.9	1381.9	1730.0	2268.2	2331.1
Mallaig	10.8	17.9	2.0	1.6	6.7	5.2	7.7	66.7
North	713.1	614.9	497.1	793.4	318.2	814.3	435.8	512.9
Orkney	1510.2	1539.2	1498.6	1362.2	1309.5	1582.2	1467.0	1539.6
Papa	684.7	694.8	771.9	785.2	463.5	454.1	838.2	797.5
Shetland	583.1	416.2	331.8	217.1	33.3	193.8	640.8	274.5
South East	480.9	148.1	96.8	23.0	129.0	166.0	273.8	519.5
South Minch	1102.2	1183.4	1247.3	1165.6	979.3	1417.7	1453.0	2314.1
Sule	1238.9	788.2	952.4	865.6	1389.7	1357.9	1663.1	1741.2
Ullapool	134.5	146.1	199.8	233.2	194.2	269.5	357.5	364.9
Total	11435.2	10252.5	9744.2	9337.0	8581.5	10408.0	12303.0	13426.9

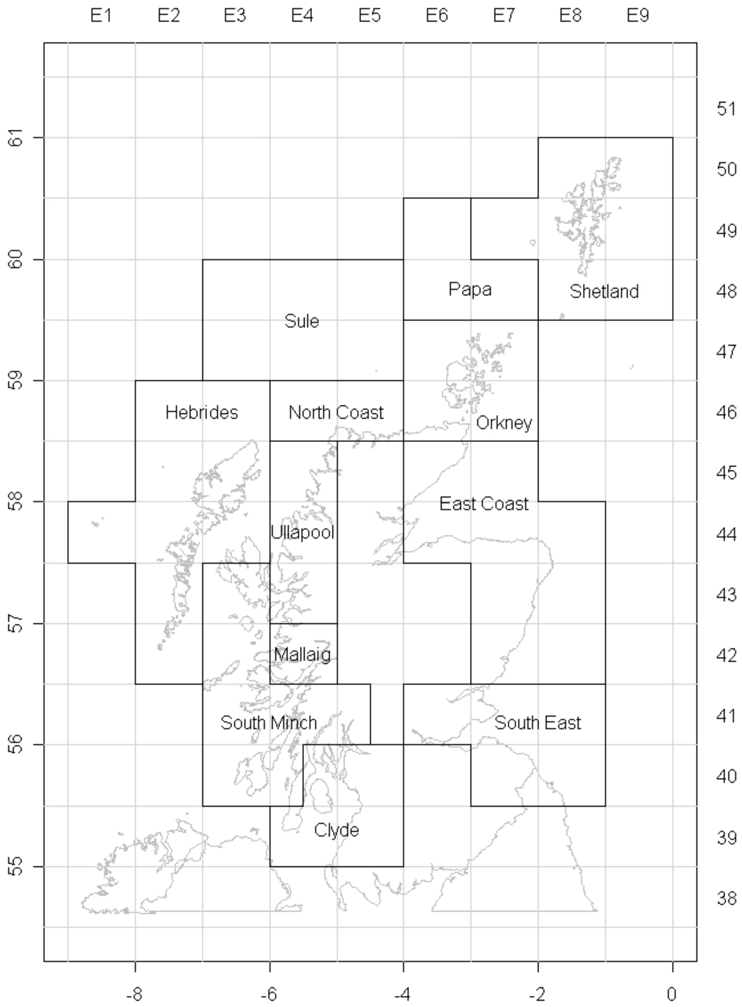

Figure 2.8. Creel fishery assessment areas in Scotland.

Assessments

Additional data are collected on the length-frequency distributions of brown crab by FRS for each of the main assessment areas and are used to conduct Length Cohort Analysis (LCA) of the brown crab population in each area. From the landings sampled it is apparent that crabs landed from the north and west of Scotland, in particular the offshore areas, are larger in size than those from the east coast. The majority (ca. 80%) of the crabs landed from offshore grounds are females. LCA indicates that brown crab is fully exploited in all areas. There is currently no catch per unit effort (CPUE) time series data for brown crab in Scotland.

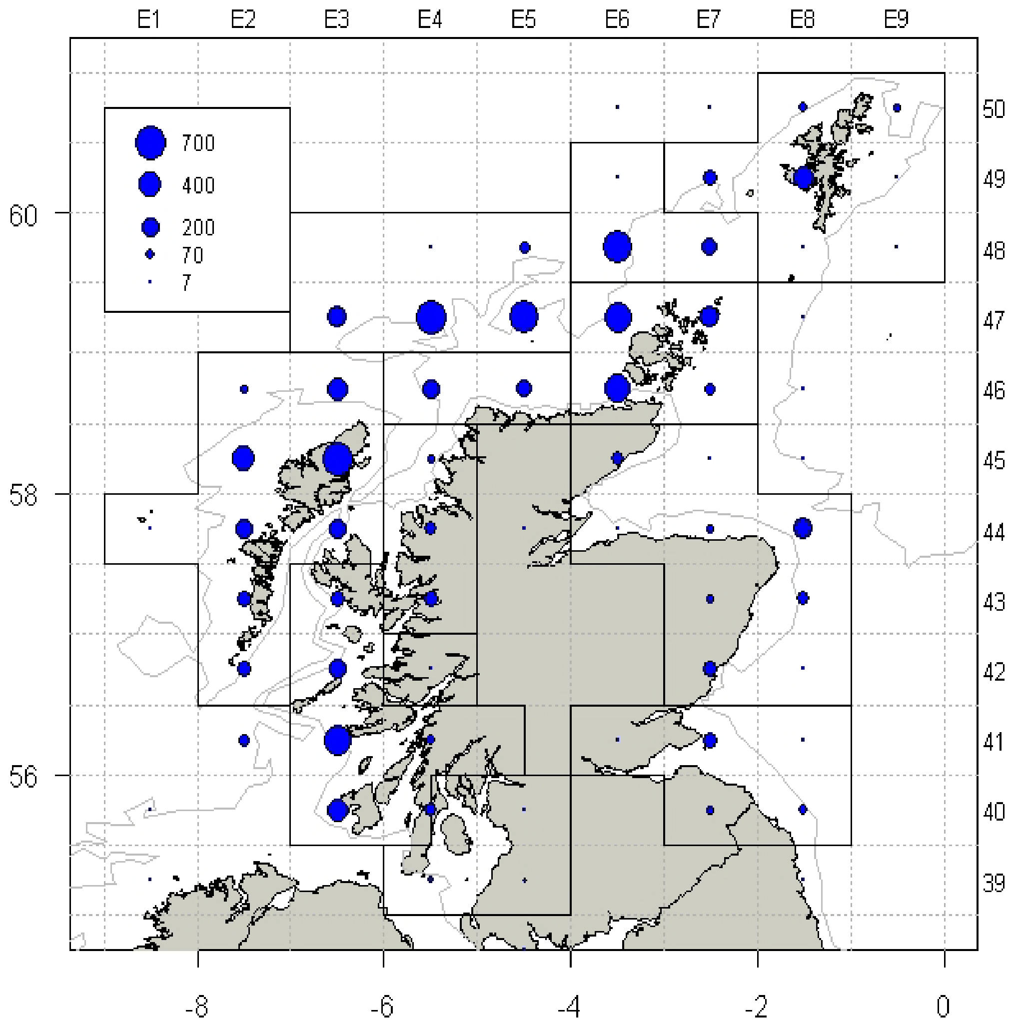

Figure 2.9. Brown crab landings into Scotland in 2007.

2.2.2.2.2 Shetland Isles

More detailed information is available for the Shetland Isles than for the rest of Scotland (Leslie *et al.*, 2008). Landings of brown crabs have shown an overall increase since the collection of data from fishermen's logsheets was introduced by the Shetland Shellfish Management Organisation in 2000. There has been some fluctuation, however, between a low of around 200 tonnes in 2002 and 2003 and a peak of almost 400 tonnes in 2006 (Figure 2.10). The landings in 2007 were above average at 322 tonnes. The changes in effort over the data collection period have shown a similar pattern to landings, albeit with a more marked decrease in the first few years (Figure 2.10). This has resulted in an initial period of relatively stable landings per unit effort (LPUE) of around 0.7 kg/creel between 2000 and 2002, followed by an increase to almost 1 kg/creel in 2004. There was then a period of stability until 2007 where a decrease in LPUE to around 0.85 kg/creel was recorded.

Analysis of LPUE data was carried out using a Generalised Additive Model (GAM). Long term trends (Figure 2.11) indicate that LPUE has increased over the reference period (2000 to 2007). 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. There were also large between vessel variations which added to the model. There are strong geographical trends in the brown crab data (Figure 2.12) with the highest LPUE to the north and west of the Isles, the lowest LPUE in the south and east, and intermediate levels between the two.

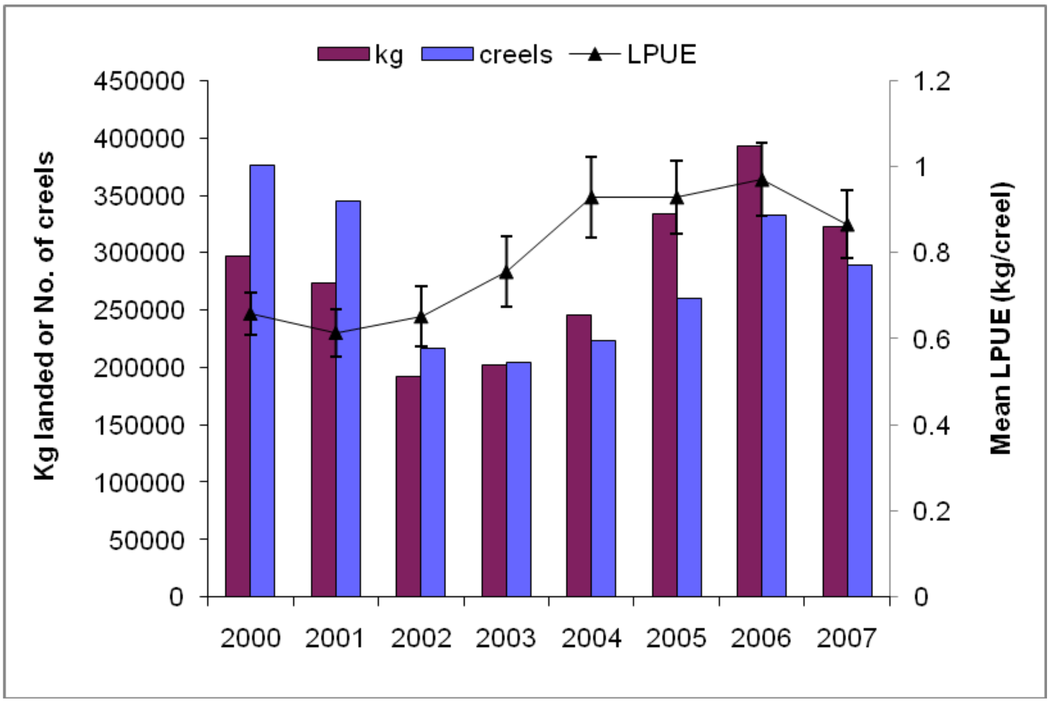

Figure 2.10. Total landings of brown crab (kg), total creels catching brown crabs and the average LPUE from SSMO logbook data with the 95% confidence intervals shown.

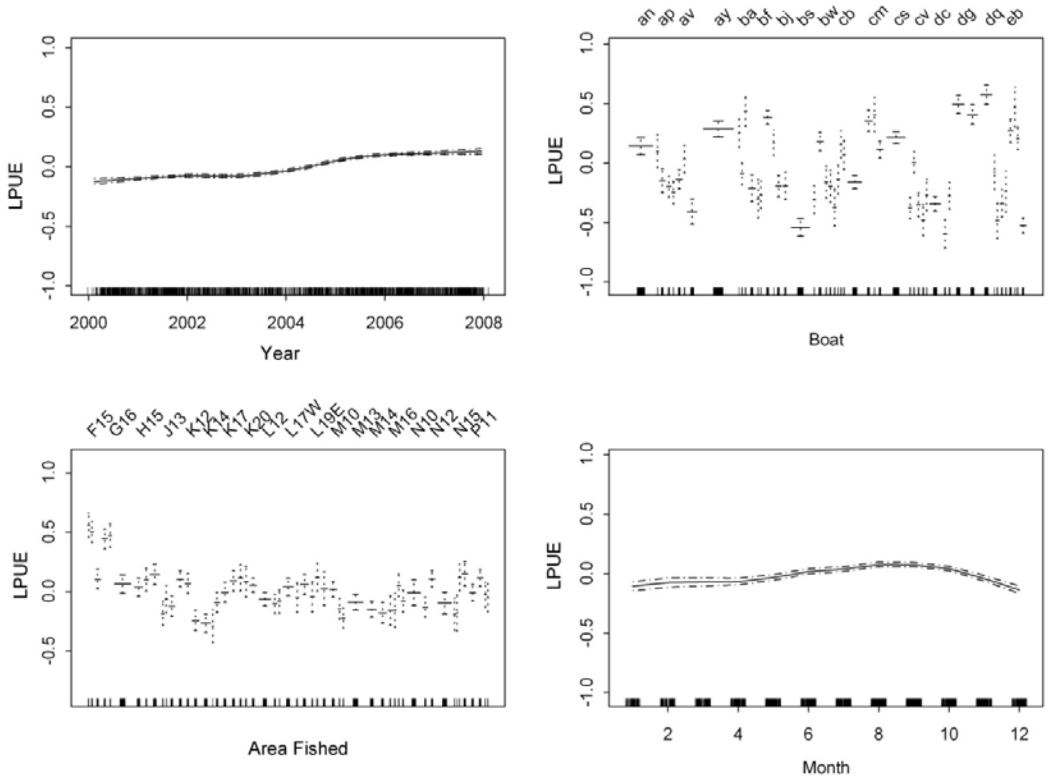

Figure 2.11. Brown crab diagnostic GAM plots of the fitted curve (continuous line) and factors included in the minimal model. Data are: Year - monthly time series from January 2000 to Dec 2007; Boat - fishing vessel; Area - SSMO statistical rectangle; Month - month of fishing regardless of year, months 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.

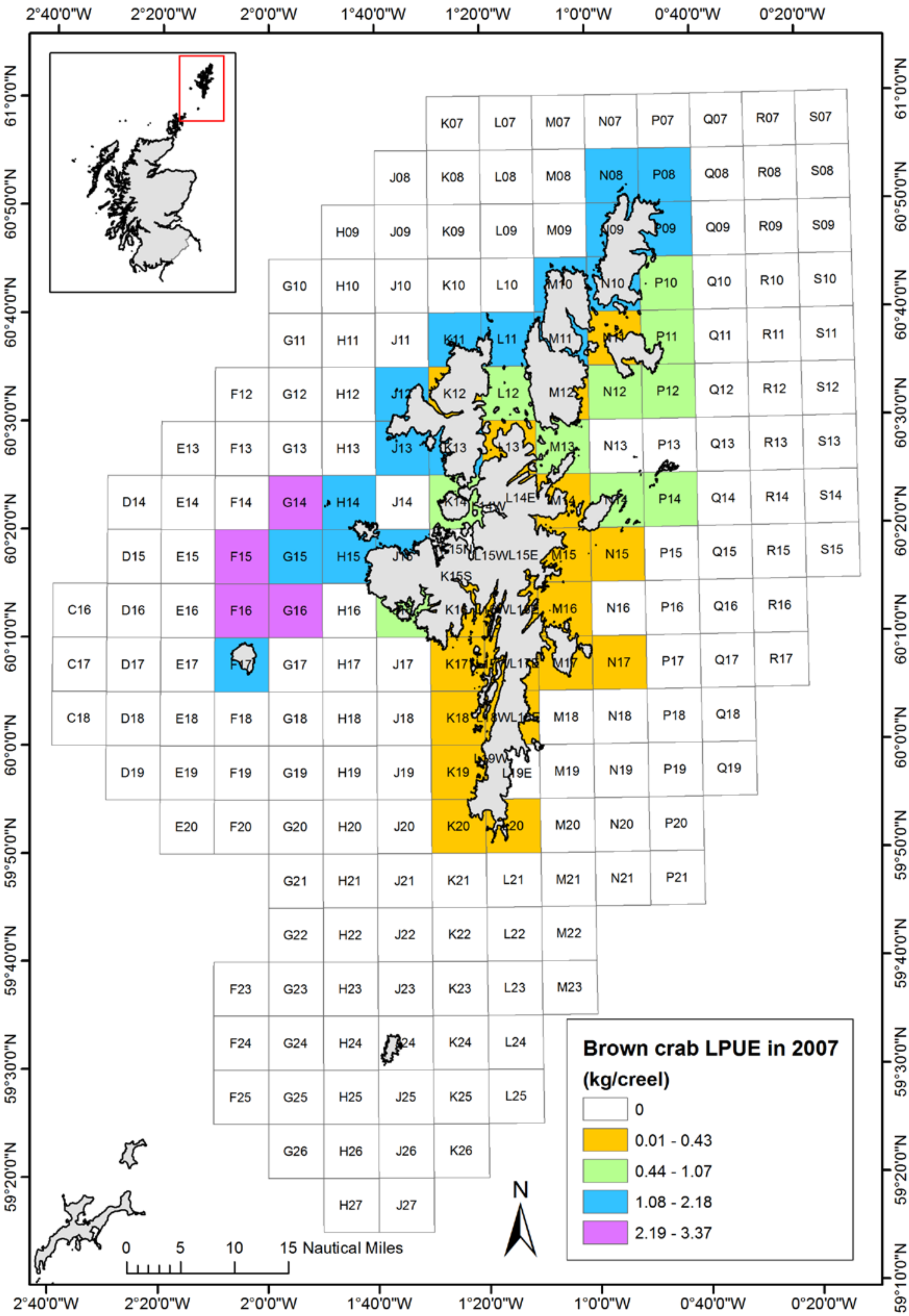

Figure 2.12. Geographical trends in mean LPUE for the brown crab fishery around Shetland in 2007.

2.2.2.3 Ireland

In 2007, 12 204 tonnes of brown crab were landed into Irish ports. This is the second heaviest landings total since 1990. An upward trend from 1990 until 2004 is suggested by high landings of 13 690 tonnes in that year. However 2004 may have been exceptional, in which case yield may have stabilised in 2001 when 10 312 tonnes were reported. There is no clear trend in landings in the period 2001–2007 inclusive although total landings have fluctuated from one year to another (Figure 2.13).

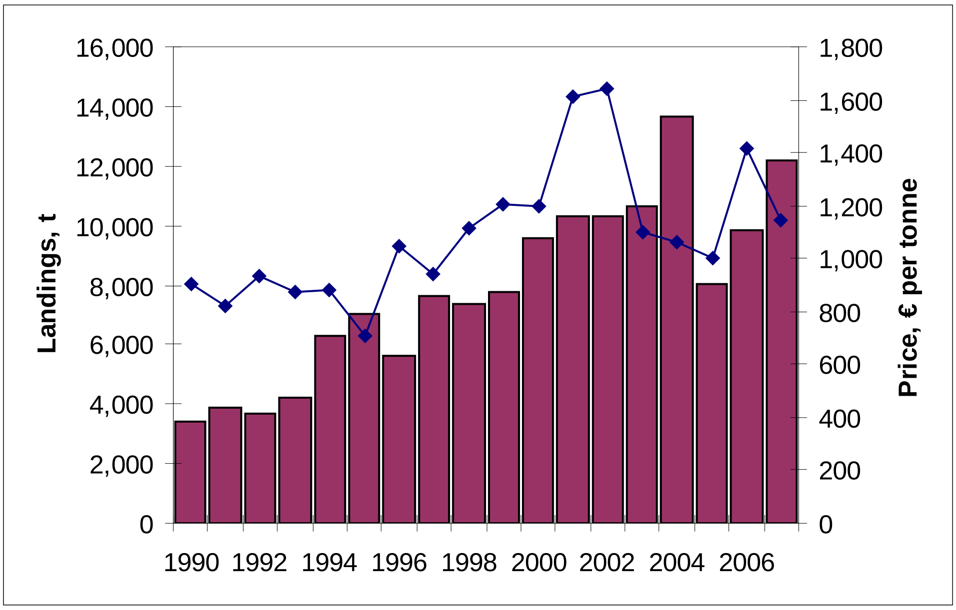

Figure 2.13. Landings and first sale values of brown crab into Irish ports, 1990–2007 inclusive.

At last year's Working Group (ICES, 2007) a visual method of comparing changes in annual landings by port was proposed. In 2006 landings of brown crab were registered at 94 landing places in the Republic; in 2007 landings took place at 81. In both years landings occurred at 65 ports and these are compared in Figure 2.14. Increase/decrease of landings in 2007 over 2006 is not confined to any coastline: 39 ports reported lower landings in 2007 than the year before while 26 registered increases.

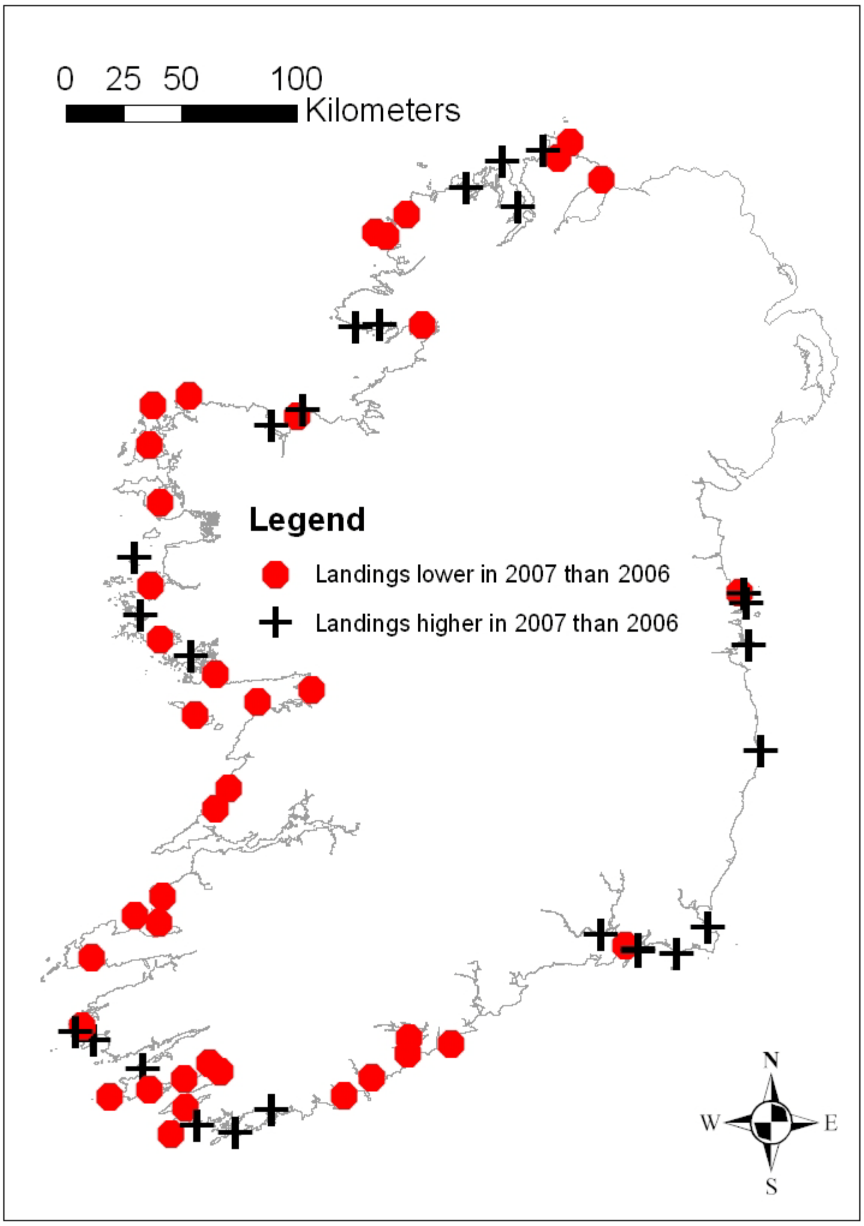

Figure 2.14. Increase/decrease in landings of brown crab in to Irish ports from 2006 to 2007.

The majority of brown crab landed into Ireland originates from Areas VIa, VIIa, VIIb, VIIg and VIIj (Table 2.2, Figures 2.15 to 2.18). On average, since 2003, 78% of landings originate from Area VIa. Approximately 44% of national landings by under 10m vessels originate here. Irish vessels over 18m in length have fished in Areas IVa and IVb since 2005. The allocation of landings to month for vessels under 10m may not be accurate.

Table 2.2. Monthly Irish brown crab landings (tonnes) by ICES area for all vessels (2003–2007).

Table 1 Monthly Irish brown crab landings (tonnes) by ICES Area for all vessels (2003-2007)

Year	Month	IVa	IVb	VIa	VIb	VIIa	VIIb	VIIc	VIIf	VIIg	VIIh	VIIj	VIIk
2003	Jan			219.43		13.25	0.36			38.01		1.77	
	Feb			262.97		10.97	0.55			39.05		8.53	
	Mar			411.94		20.72	0.68	0.10		49.19		50.27	0.05
	Apr			306.24		26.39	30.24	0.10		54.86		71.49	
	May			308.56		55.82	37.79			51.42		181.68	
	Jun			414.22		79.35	39.75			34.82		241.75	0.04
	Jul			383.50		122.98	46.66	2.82		51.67		286.62	
	Aug			544.49		133.85	57.10	5.00		55.07		195.87	1.74
	Sep			517.89	10.75	157.29	64.37			58.24		248.34	
	Oct			790.74	21.95	152.24	27.44	0.03		42.02		179.04	0.03
	Nov			752.87	9.31	124.65	19.59	0.23		40.41		101.21	
	Dec			593.16		11.95	7.84			27.37		84.51	
2004	Jan			289.28		0.12	11.43			45.00		14.59	
	Feb			352.50		0.34	12.63	0.11		41.45		14.49	0.04
	Mar			320.57		0.18	17.34			56.25		32.34	
	Apr			346.73		0.02	69.14			43.82		49.43	
	May			409.33		0.43	100.34			60.95		78.91	
	Jun			337.02		0.91	75.85	0.08		29.92		69.31	
	Jul			366.17		0.98	65.08			39.48		26.57	
	Aug			630.43		6.24	61.77			48.65		36.93	
	Sep			648.25		19.27	39.98		0.21	49.20		25.47	
	Oct			798.98		18.91	28.03	0.06		40.74		32.85	0.03
	Nov			715.23		19.14	21.50			41.20		11.64	0.12
	Dec			1811.34		1041.46	864.74			33.44		2632.27	
2005	Jan			238.09		26.10	32.53			38.06		2.10	
	Feb			291.51		32.71	3.97	0.21		37.15		18.15	
	Mar			360.14		61.44	3.92	0.23		47.71		16.97	
	Apr			388.35		40.20	7.46	0.11	10.00	35.03		46.05	
	May			400.14		71.94	2.57			48.62		105.82	0.04
	Jun			336.96		156.85	2.67			27.78		128.36	
	Jul			421.24		169.35	4.23			37.72		108.30	
	Aug			564.63		192.10	32.27			39.60		113.38	
	Sep			565.43		176.85	41.10			58.69		89.25	
	Oct			693.50		114.26	37.49			58.26	0.13	66.17	
	Nov	6.15		87.17		67.07	27.47		4.50	37.04		3.28	
	Dec	65.09		1127.98		59.07	454.92			32.37		255.85	
2006	Jan	58.25		1497.79		4.56	32.76			28.90	17.14	275.29	
	Feb	23.75		192.04		1.94	21.60			28.72		2.18	
	Mar			242.61		18.00	27.78			41.84		6.65	
	Apr			239.75		2.19	31.16			33.24		11.27	
	May			286.43		2.54	32.65			33.68		8.73	
	Jun			300.47		20.30	27.45			7.41		9.73	
	Jul	23.60		337.64		7.65	35.83			3.20	0.10	24.04	
	Aug	62.55		355.94		16.54	78.83			2.13	0.04	22.43	
	Sep	61.45	17.45	365.69		39.82	77.63			0.31		17.83	
	Oct	88.52	77.05	331.40		17.35	58.08			0.33		14.35	
	Nov	42.70	39.85	293.39	11.80	9.42	33.71			0.42		5.87	
	Dec	12.29	68.40	948.95		16.90	1198.67			152.70		1163.81	
2007	Jan		58.55	159.63		1.23	6.06			0.26		0.75	
	Feb		3.05	193.29		1.72	50.86			0.37		0.10	
	Mar			208.50		3.58	15.85			0.15		0.88	
	Apr	0.13		293.47		7.78	52.20			0.52		5.11	
	May		17.93	292.96		14.96	95.72			3.34		12.87	
	Jun		26.90	362.93		23.86	96.00			2.18		33.15	
	Jul	59.20	80.25	321.17		30.29	117.16			4.17		43.89	
	Aug	43.78	88.25	2629.97		49.15	148.91			4.50		39.97	
	Sep	12.35	161.83	1767.10		39.28	113.87			9.88		51.47	
	Oct		193.43	1513.57		59.53	99.30		0.03	21.63		31.75	
	Nov		156.25	211.64		28.57	26.04			4.38		9.91	
	Dec		129.18	691.76		150.64	4.46			0.46		497.55	

Figures 2.15 to 2.18. Monthly landings (tonnes) of brown crab (*Cancer pagarus*) into Ireland from the most regularly fished ICES Areas (2003–2007). The ICES Areas differ in significance for >10 m and < 10 m vessels.

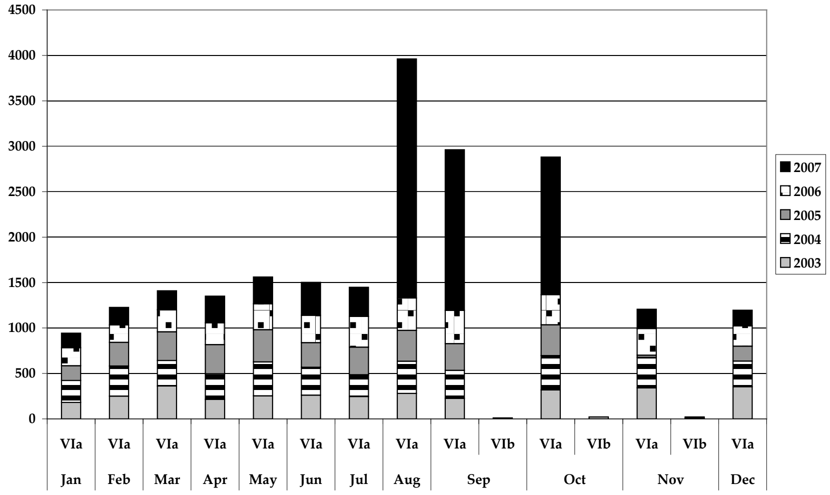

Figure 2.15. ICES Areas VIa & VIIa for vessels < 10 m

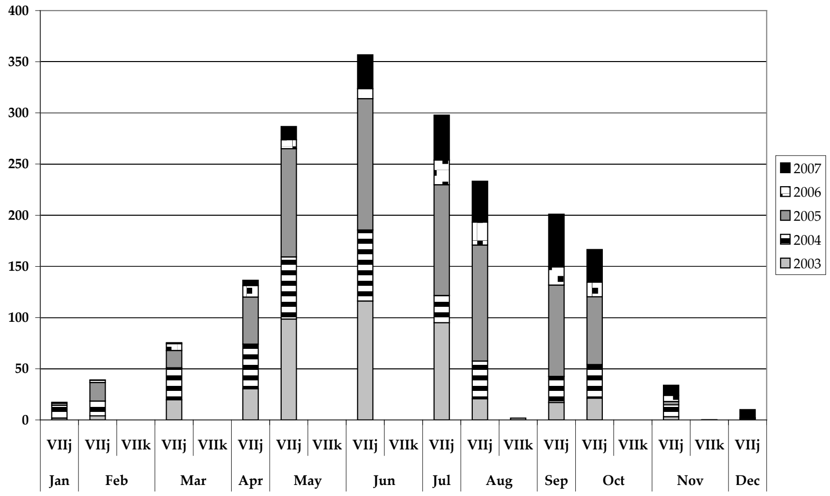

Figure 2.16. ICES Areas VIIb, VIIg & VIIj for vessels < 10 m

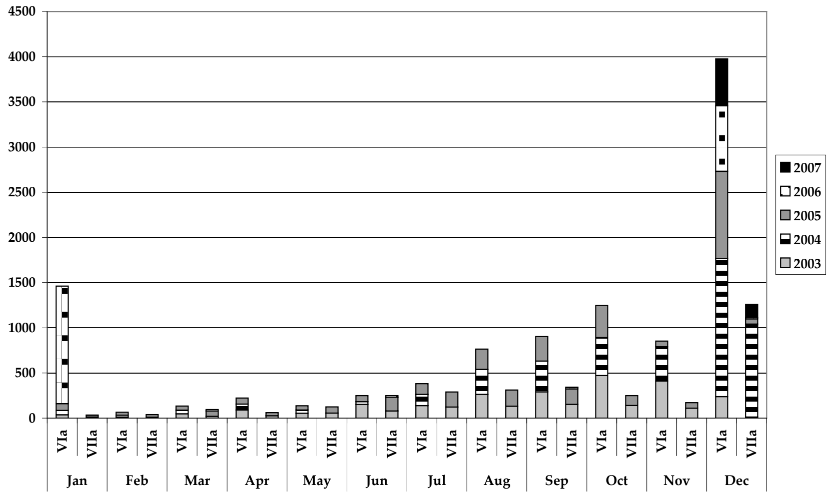

Figure 2.17. ICES Areas VIa & VIb for vessels > 10 m

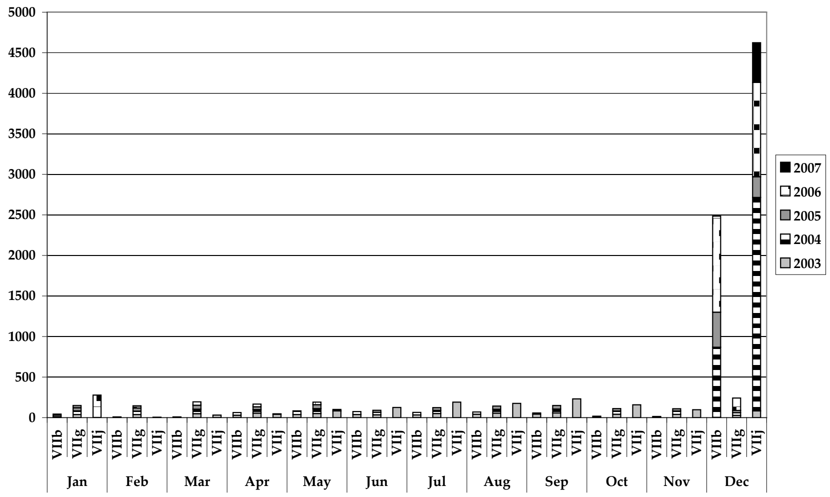

Figure 2.18. ICES Areas VIIj & VIIk for vessels > 10 m

Landings per unit effort

Area VIIj (inshore)

Data from private diaries and fishing activity records acquired from the boats were compiled to provide estimates of LPUE in the inshore fleet in VIIj (Figures 2.19 and 2.20). The dataset represents 12770 strings of pots or approximately 0.5 million pot hauls between May 2000 and October 2007 mainly from 1 vessel targeting crab throughout the year. LPUE varied seasonally and between years. Soak times ranged from 24 to 264 hours but 63% of fishing events had soak times of 24–72 hours. Peaks in LPUE occurred generally in August and were at a minimum in the October to March period. Average monthly LPUE declined during the period from approximately 2.4 to 1.4 kgs per pot haul. Annual LPUE declined from 2.5 in 2007 to 1.7 in 2004. Between 2004 and 2007 annual average LPUE varied between 1.76 and 1.57.

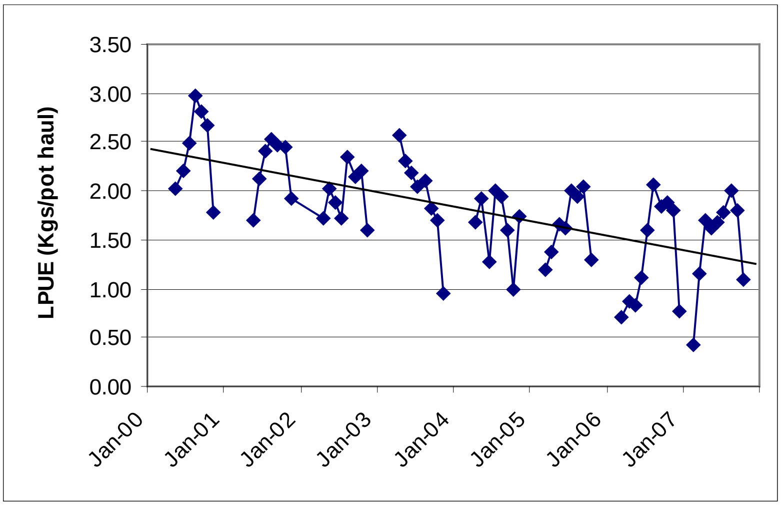

Figure 2.19. Trend in average monthly LPUE in the Irish inshore brown crab fishery in Area VIIj between 2000 and 2007 (source: Gavin Power IS&WPO).

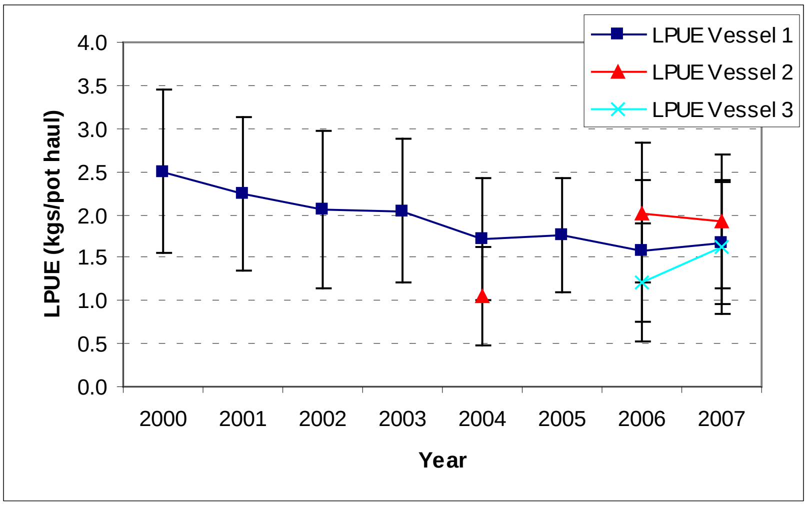

Figure 2.20. Annual average LPUE for 3 vessels in the Irish inshore brown crab fishery in Area VIIj between 2000 and 2007.

Area VIa (inshore)

Data from private diaries and fishing activity records submitted voluntarily by 18 inshore (<13 m) vessels off the north west coast of Ireland (Area VIa south) were compiled for the years 1993–2007. The dataset represents approximately 2.5 million pot hauls and 5388 fishing records mostly on the scale of daily vessel reports but some on a finer scale of individual fishing operations (strings of traps). Discard data are available for the period 2002–2007. Gear soak times usually ranged from 48–72 hours.

Analysis of variance shows significant skipper, month, year and month*year interactive effects on LPUE. The data are not standardised. There was strong seasonal variation in LPUE with minima generally occurring in the first half of each year and maxima occurring in late autumn (Figure 2.21). Annual average LPUE was stable during the period ranging from 1.5 (1993, 1996, 2003, 2004) to 2.5 (2001) (Figure 2.22). Discards per unit effort (DPUE) also showed strong seasonal and skipper effects but weaker annual effects in comparison to LPUE. DPUE reached maxima in the June-September period presumably following the summer moult (Figure 2.23).

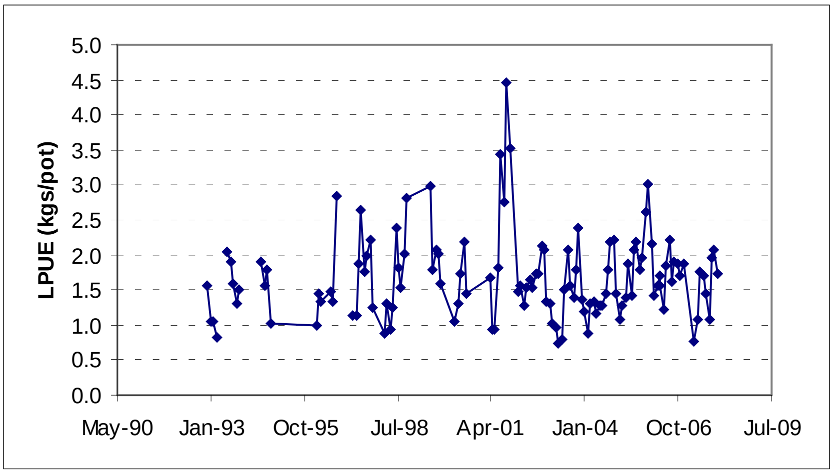

Figure 2.21. Monthly average LPUE for crab in the Irish inshore fleet operating in Area VIa south.

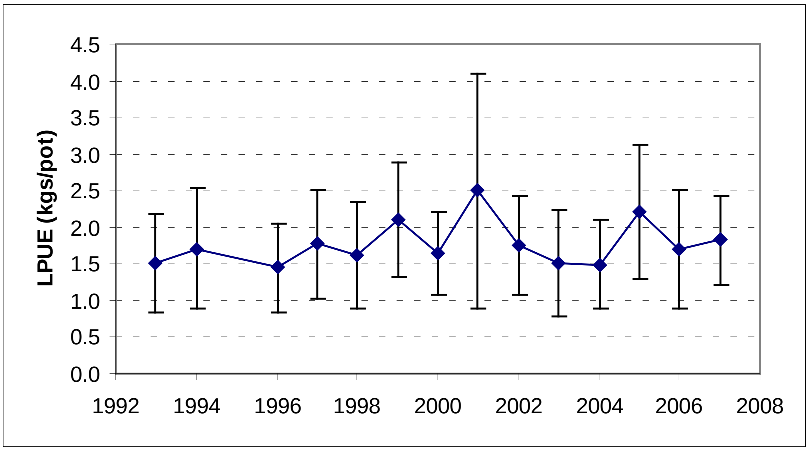

Figure 2.22. Annual average LPUE for crab in the Irish inshore fleet operating in Area VIa south.

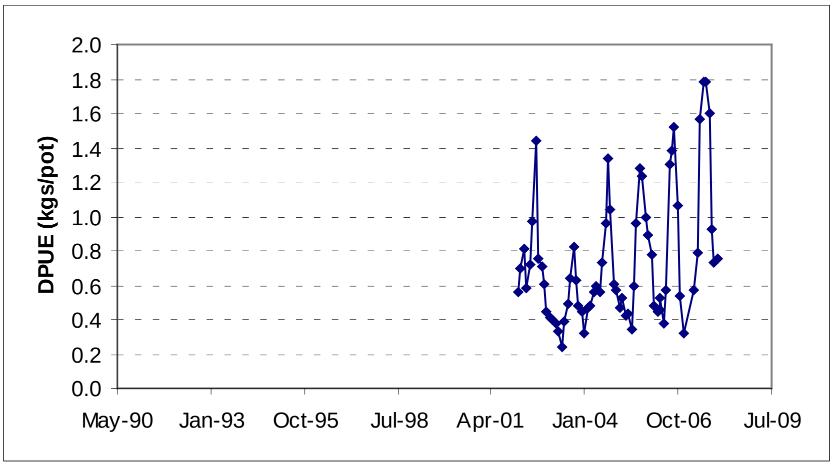

Figure 2.23. Monthly average DPUE for crab in the Irish inshore fleet operating in Area VIa south.

2.2.2.4 France

Potting vessels constitute 75% of the fleet in the French fishery for brown crab, with the remaining 25% of the landings coming from netters and trawlers. Data on landings and fishing effort are very accurate for the offshore fleet as fishing position is available for each day. Landings can be extrapolated from log book sheets, but it is very difficult to obtain an accurate estimate of overall fishing effort. Trends in LPUE are available for the larger vessels, and for some small inshore vessels, private log books are available.

The data from the offshore potting fleet are used to estimate an abundance index. The quality and the long time series of these data allow the development of a robust index. The index abundance is estimated by fitting a GLM model to the data. The model parameters are the year, the month and the area. The lowest level of crab landings for many years was seen in 2006, but LPUE was very high in 2007, although it is not known whether this was due to a very good recruitment or to some other unknown factor. As with the crab fishery on the English south coast, the seasonal trend shows the highest LPUE in the autumn.

2.2.2.5 Norway

The fishery for brown crab *Cancer pagurus* 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. The crab fishery has expanded northwards (Table 2.3). There are smaller, but important regional coastal crab fisheries extending south. In the southernmost part the fishing season starts in April and lasts until November.

In 2001 a programme for mapping biological data of the brown crab resource was initiated. The logbooks provide data on catch-rates (Table 2.4), 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 2007 as in the years before. Due to a newly started fishery it may be expected that the catch rates would increase as the fishers find the best grounds. This is confirmed by the results in 2007 and the catch rate is higher than in the other areas. It seems also that the size of the crab is larger in the later years.

In area 06 (Helgeland and N-Trøndelag) the catch rates are still high and no trend is observed (Table 2.4). The ratio of females in the landings is stable. The size of the crab does not seem to change.

In area 07 (S-Trøndelag, Møre and Romsdal) the catch rates are stable during the period, although an increase is seen in the two later years. Fewer small males are observed in the later three years, and the female catch rates by length seem to be the same during the whole period.

In 2005 and 2006 there were no fishers reporting from the south-west (area 08). In 2007 there were four fishers reporting, although not from the same localities as in the earlier years. The data show that the crabs in this area are caught at smaller size than in the northern areas, however the size of the crab in 2007 is larger than the earlier years.

The catch-rates in 2007 vary between the areas, 4.46–1.86kg/trap for landed crab and 2.86–1.11kg/trap for discards. The catch rate of landed crab seems to be of a comparable size in all the northern areas and this may reflect an overall density of crab. The catch rates of discards still differ in the areas, being substantially lower in the northernmost area.

As the catches are increasing, as well as the CPUE, there appears to be no reduction in the available stock of brown crab in the Norwegian waters. Preliminary 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.

Preliminary 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, but the landings may also vary due to variation in stock density in fully exploited areas.

Table 2.3. Norwegian landings (tonnes) of brown crab (*Cancer pagurus*) from 1996 to 2006 reported to the Norwegian Directorate of Fisheries. The areas are the official statistical fishing areas.

Area	Name	Geograph.	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
05	Vesterålen	67°-70° W11°	0	0	0	1	1	17	2	5	1	2
00	Lofoten	67°-68.5° E11°	0	1	1	2	2	28	54	298	335	510
06	Helgeland, N-Trøndelag	64°-67°	476	598	718	684	800	1589	2012	2392	2768	4172
07	S-Trøndelag, Møre and Romsdal	62°-64°	1711	1440	1499	2115	2676	2247	1994	1858	2116	2610
28	Mid-Norway	60°-62°	277	257	206	241	366	532	503	486	332	461
08	SW-Norway	57°-60° W7°	518	540	465	430	496	527	676	625	637	706
09	Skagerak	57°-60° E7°	1	1	1	2	4	4	5	7		
Total			**2984**	**2836**	**2890**	**3476**	**4344**	**4944**	**5248**	**5671**	**6189**	**8461**

Table 2.4. 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).

	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	1.26	0.78	3.05	0.77	2.03	0.89		
2002	1.11	0.59	3.13	1.13	2.39	0.97	1.12	1.64
2003	1.28	0.33	2.57	0.90	2.27	1.07	1.20	1.65
2004	2.35	0.45	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

2.2.2.6 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. In Jersey, the crab fishery is mainly a by-catch in the lobster fishery with the entire commercial fleet consisting of approximately 200 vessels with 160 of these being under 10 metres in length. Landings are 400–500 tonnes per annum. All vessels have to provide annual statistics, but since 2006 it is now obligatory to provide full landings and effort data split between gear targeted at each species. There is a maximum pot number that each vessel can fish with that maximum set by the length of the vessel. There is also a significant fishery for *Cancer pagurus* in Guernsey in deeper waters.

There are *Cancer pagurus* fisheries in many other countries such as Belgium, Denmark and Sweden, 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 crab (*Necora puber*)

2.2.3.1 Scotland

2.2.3.1.1 National statistics

The Scottish velvet crab fishery was originally very small scale and only operated for a few months in the year. The fishery expanded in the 1980s and is now very important in some inshore areas. Scottish fishery statistics landings data for velvet crab are available from 1985 onwards. The three main landings areas are the Hebrides, Orkney and South Minch, landing a combined total of ca. 75 % of the national landings (Table 2.5). Small quantities are also landed from the Mallaig and Ullapool areas (Figure 2.24). In the last 5 years, landings from the East and South East areas have increased to account for 5.5 and 11.5 % of the national landings respectively. Over the past seven years national landings have fluctuated, peaking in 2003 at 3800 tonnes. In 2007 the total landings were approximately 2800 tonnes.

Table 2.5. Annual velvet crab landings from 12 Assessment areas in Scotland from 2000–2007.

Area	Year							
	2000	2001	2002	2003	2004	2005	2006	2007
Clyde	112.0	37.6	12.9	15.6	8.3	15.2	26.9	17.4
East	66.4	73.1	151.2	303.5	274.9	96.9	297.5	414.3
Hebrides	301.5	228.1	299.3	619.3	536.8	250.1	291.1	313.3
Mallaig	135.6	56.1	14.2	7.7	19.4	15.1	33.3	21.0
North	0.7	0.9	4.0	7.6	4.1	0.0	8.2	4.2
Orkney	698.2	676.7	712.8	1407.6	1507.0	807.2	840.6	923.0
Papa	2.1	7.1	6.0	1.6	2.4	0.1	5.5	2.4
South East	17.2	13.1	22.8	95.5	138.9	69.5	152.7	189.9
Shetland	54.8	76.0	6.4	3.6	3.4	2.3	99.7	173.6
South Minch	1008.9	891.1	824.7	1223.0	708.9	462.9	764.7	728.8
Sule	0.4	0.8	0.1	10.4	2.6	1.3	0.0	0.0
Ullapool	43.5	87.3	110.5	176.6	179.7	58.6	68.3	59.2
Total	2443.2	2149.9	2166.8	3873.9	3388.4	1781.3	2590.5	2849.2

Assessments

Length frequency data are collected by FRS Marine Laboratory, Aberdeen for assessment purposes. The sampled landings indicate that approximately equal number of males and females are exploited in all areas except the South East where significantly more males are landed. Length Cohort Analysis was carried out for areas where there is sufficient length frequency data available and indicates that velvet crab is fully exploited in most areas. There is currently no catch per unit effort information available for velvet crab in Scotland.

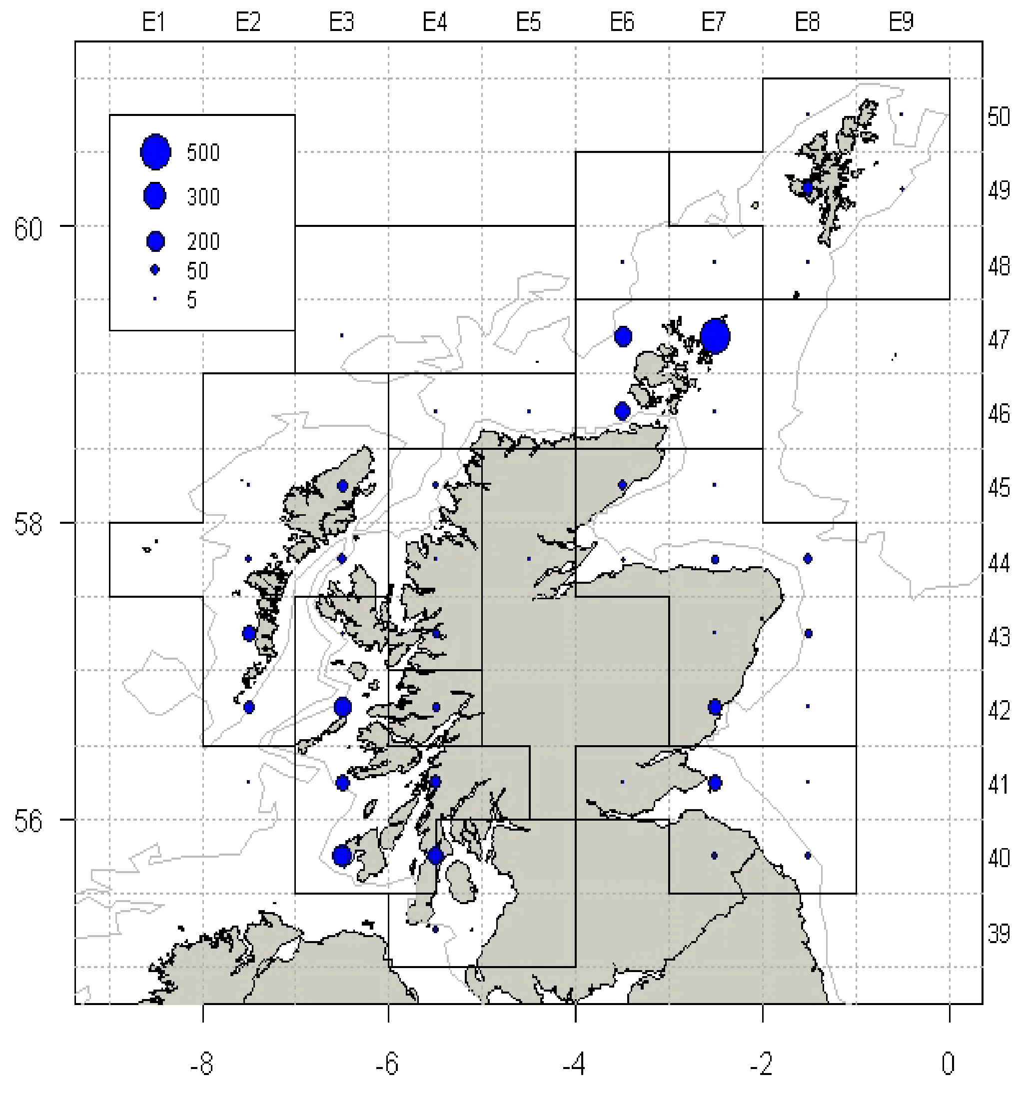

Figure 2.24. Velvet crab landings into Scotland in 2007.

2.2.3.1.2 Shetland Isles

In recent years landings of velvet crabs have fluctuated considerably, but the general pattern has been one of increase since data collection began in 2000 (Figure 2.25). The data collected from fishermen's logbooks show that there was a substantial increase in landings in 2007 to 148 tonnes, which is the highest ever recorded value. There has been a degree of variability in the number of creels fished for velvets and the associated landings (Figure 2.25). Effort has increased over the last four years along with a concurrent and marked increase in landings over this period, which has resulted in increasing LPUE (Figure 2.25). In 2000 the mean LPUE was just under 0.3kg per creel and this has more than doubled to almost 0.7 kg per creel in 2007, which was an increase of 0.2 kg/creel from the previous year.

Analysis of the trends in LPUE using a GAM also showed an increasing trend in LPUE over the period of data collection (Figure 2.26), with a marked increase between 2005 and 2007. Seasonal effects indicate that LPUE decreases from January to April and then shows a period of increase until September, however, these are affected by summer closed periods in the fishery. 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). Area effects and vessel effects were very variable.

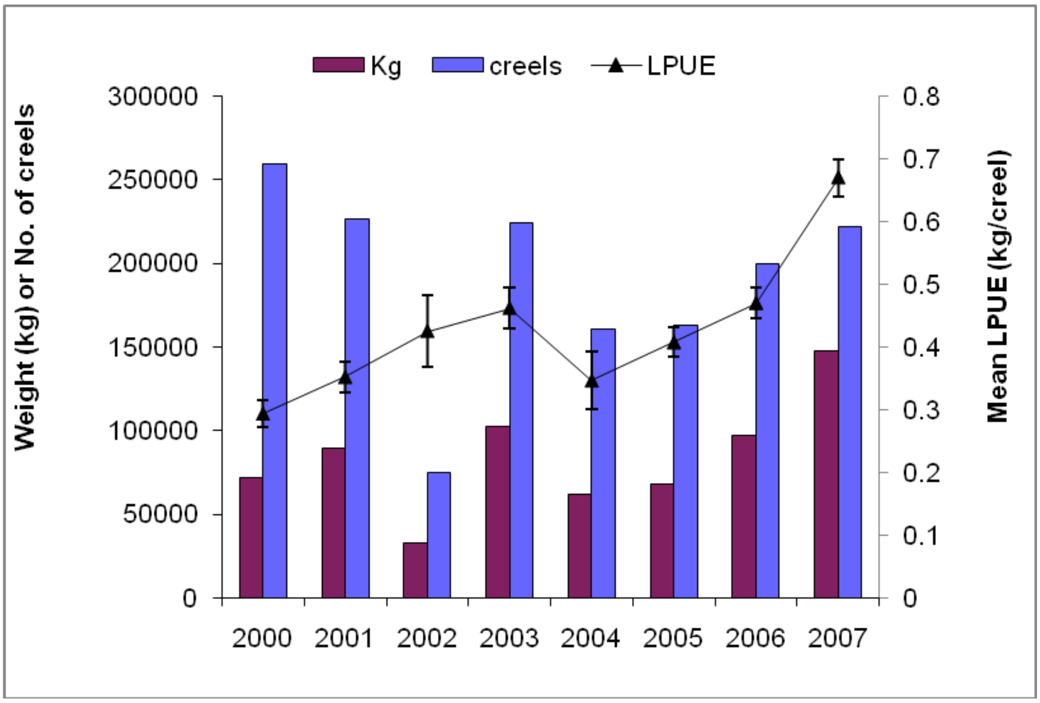

Figure 2.25. Total velvet crab landings (kg), total numbers of creels catching velvet crabs, and the average LPUE obtained from SSMO logbook data with 95% confidence intervals shown.

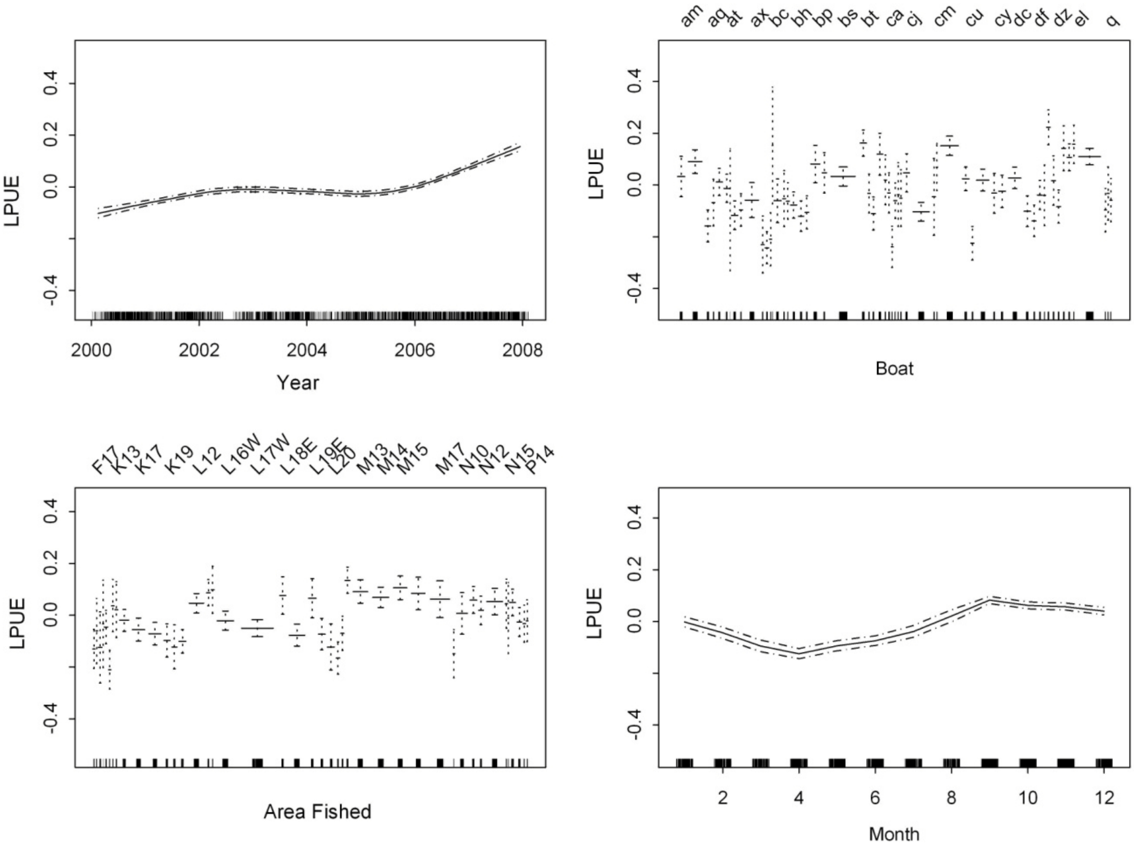

Figure 2.26. Velvet crab diagnostic GAM plots of the fitted curve (continuous line) and factors included in the minimal model. Data are: Year – a monthly time series from Jan 2000 to Dec 2007; Month - month of fishing regardless of year, months are represented by numbers commencing with 1 ~ January; 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 Red king crab (*Paralithodes camschaticus*)

2.2.4.1 Norway

The fishery for the red king crab in the Barents Sea started as a research fishery in the Norwegian and Russian zone separately, but coordinated by the Russian-Norwegian Fishery Commission in 1994. In the first year only 4 vessels participated on the Norwegian side but this increased to almost 130 in the last year of the research fishery in 2001. The main rationale behind the research fishery was to achieve biological and stock knowledge of the crab, and to develop a fishery. In the late 1990s the fishing gear changed from a conical shaped trap type to a more efficient square collapsible trap type (Table 2.6), developed specially for handling on small coastal vessels (< 15 m) that constitute the main fleet in the Norwegian king crab fishery. Research surveys using swept area give estimates of stock biomass, and size distribution data provide a recruitment index one or two moults before they recruit to the fishery.

The red king crab in the Norwegian zone has been assessed annually using a straight forward area swept method. Crab density measures are established using a 6 meter wide beam trawl and each haul last 30 minutes. The main challenge in using a trawl is that it demands smooth bottom substrate for proper sampling, and parts of the surveyed areas have a rough and stony bottom. Therefore, a trap survey has been carried out simultaneously with the trawl survey. From 2008 onwards, the fishery management advice for the king crab will be strengthened by the application of a Bayesian stock model in the assessment.

Table 2.6. Catch per unit of effort (crabs/trap/day) in the Norwegian research fishery (1994–2001) and commercial fishery (2002–2006) for the red king crab *Paralithodes camtschaticus*.

Year (trap type)	Males	Females
1994 (conical)	0.607	0.609
1995 (conical)	1.201	0.973
1996 (conical)	0.891	1.190
1997 (conical)	0.992	1.336
1998 (conical)	1.204	3.251
1998 (square)	2.913	5.924
1999 (conical)	0.658	0.757
1999 (square)	3.166	5.042
2000 (square)	4.453	8.450
2001 (square)	13.311	25.028
2002 (square)	9.171	20.396
2003 (square)	6.568	11.633
2004 (square)	7.957	8.029
2005 (square)	9.376	6.814
2006 (square)	10.465	12.885

2.2.5 Snow crab (*Chionocoetes opilio*)

2.2.5.1 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.

2.2.5.2 Greenland

The historical development of the crab fishery in Greenland is shown in Table 2.7 (only data from 2000 to 2007 is shown in the table). Total landings from all management areas increased from approximately 1000 tons (no TAC) in 1995 to a peak of approximately 15 000 tons (TAC 26 800 tons) in 2001. From 2001 to 2006 the total catch has decreased by approximately 77% to 3305 tons (TAC 5700 tons) despite the quota not being reached.

The distribution of the landings in each management area shows that traditionally most of the landings have predominantly come from the areas Disko Bay-Uummannaq, Sisimiut and Nuuk-Paamiut (Table 2.7 and Figure 2.27). Commercial CPUE is derived from catch and effort data from logbooks (Burmeister & Siegstad, 2008).

The total fishing effort (trap hauls) has declined by 81% since 2001 (from 3416 to 665 thousand trap hauls during 2001–2006). The decline has been mostly due to a declining number of participants in the fishery. Preliminary and incomplete logbook data for 2007 shows total effort is 240 thousand trap hauls. The ratio of total landings to logbooks landing varies between management areas. The overall distribution of the fishery along the West coast of Greenland from 2003–2007, derived from available logbook data is shown in Table 2.7.

The number of vessels with licenses to participate in the snow crab fishery increased by more than a factor of 3 from approximately 120 to 374 boats from 1999-2002. Since then the number of both large and small vessels have decreased substantially as the abundance of the resource has also declined. From 2004 to 2007 the number of active license holders in all management areas decreased by 55%. The reduction was 60% in inshore Disko Bay (I-DIS) and 57% in the offshore area of Nuuk-Paamiut (O-NUP).

There are no specific long-term management objectives for the snow crab resource in West Greenland, however since 2004 the main objective of recommendations from Greenland Institute of Natural Resources (GINR) has been to stop the decline in biomass of the crab resource in the different management areas. The recommendations are not expected to result in increased stock biomass in the short term, but only stop the current decline. If a rebuilding of the stock to achieve a higher exploitable biomass and better catch rates is the objective, then the recommended catches should be further reduced to allow the stock to grow.

Table 2.7. Catches, catch rates (CPUE) and effort in management inshore and offshore areas along the West coast of Greenland from 2000–2007. *2007 data is preliminary and incomplete.

Management Area	Year	Total catch (tons)	Quota	Inshore catch (tons)	Inshore CPUE (kg/trap)	Inshore effort ('000)	Offshore catch (tons)	Offshore CPUE (kg/trap)	Offshore effort ('000)
Upernavik	2000	--	--	--	--	--	--	--	--
	2001	--	--	--	--	--	--	--	--
	2002	--	--	--	--	--	--	--	--
	2003	--	--	--	--	--	--	--	--
	2004	65	--	--	--	--	--	--	--
	2005	--	100	--	--	--	--	--	--
	2006		0						
	2007*	--	0	--	--	--	--	--	--
Uummannaq-Diskobugt	2000	3,052	--	2,940	4.8	613	112	5.5	20
	2001	4,202	--	3,950	3.1	1,274	252	3.6	70
	2002	3,319	--	2,970	3.3	900	349	3.0	116
	2003	2,739	--	2,482	3.7	679	257	2.6	97
	2004	2341	--	2174	3.4	632	167	3.7	45
	2005	1499	1718	1402	3.8	365	98	4.0	24
	2006	1134	1600	1008	4.6	219	126	6.7	19
	2007*	473	1530	348	4.0	88	126	5.1	25
Sisimiut	2000	2,534	--	491	2.8	175	2,043	6.4	319
	2001	2,606	--	327	2.9	113	2,275	4.6	495
	2002	2,724	--	473	4.6	103	2,251	3.5	643
	2003	1,633	--	692	3.7	187	941	3.1	304
	2004	1,432	--	1,111	3.9	286	321	4.9	65
	2005	1,125	900	914	6.5	141	211	6.3	34
	2006	926	700	725	8.3	87	201	11.1	18
	2007*	517	850	344	8.8	39	173	13.0	13
Maniitsoq-Kangaamiut	2000	944	--	563	4.3	131	381	7.6	50
	2001	1,835	--	1009	3.7	273	826	5.0	165
	2002	1,775	--	1032	3.8	272	743	2.7	275
	2003	486	--	40	3.5	12	445	2.8	160
	2004	115	--	78	2.4	33	38	2.1	18
	2005	73	200 (inshore)	62	4.3	15	11	3.8	3
	2006	72	100 (inshore)	60	4.3	14	12	4.3	3
	2007*	154	300	11	2.9	4	143	10.3	14
Nuuk-Paamiut	2000	3,769	--	2,430	5.3	458	1,339	5.4	248
	2001	5,077	--	4,157	5.3	784	920	3.8	242
	2002	2,531	--	1,770	2.8	632	761	2.8	272
	2003	2,315	--	704	3.4	207	1,611	4.2	385
	2004	1,795	--	180	4.5	40	1,615	8.0	203
	2005	2,295	--	316	8.4	38	1,980	8.1	244
	2006	1,173	1,800	199	6.9	29	974	6.9	140
	2007*	423	1,600	66	7.3	9	358	7.2	50
Narsaq-Qaqortoq	2000	2	--	0	--	--	2	--	--
	2001	822	--	822	--	--	0	--	--
	2002	643	--	642	--	--	1	--	--
	2003	133	--	123	--	--	10	--	--
	2004	541	--	32	3.9	8	2	1.0	2
	2005	76	--	76	8.3	9	--	--	--
	2006	0	--	--	--	--	--	--	--
	2007*	0	--	--	--	--	--	--	--

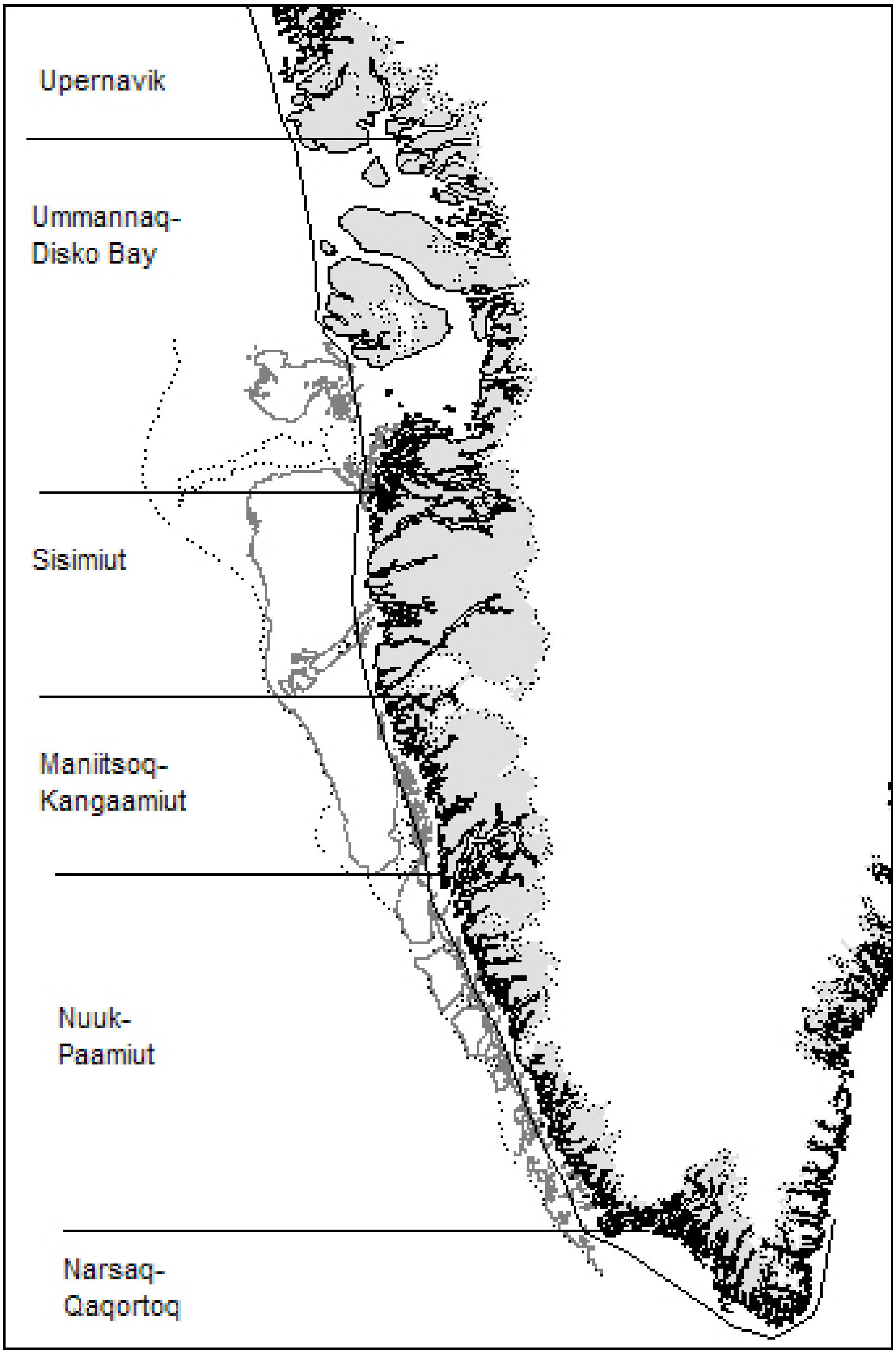

Figure 2.27. Map of West Greenland outlining the 6 management areas for the snow crab fishery.

2.2.6 *Carcinus maenas*

Crustacean traps are potentially sex and size biased (Williams and Hill, 1982; Addison and Lovewell, 1991), and the activity levels of crabs may influence catchability (Crothers, 1968); however, Catch Per Unit Effort (CPUE) data are widely used as a proxy for relative crab abundance. Thus, the abundance of the shore crab, *Carcinus maenas*, was estimated on commercial mussel beds in the Menai Strait, North Wales, using an underwater television camera (see Murray *et al.*, 2007 for detailed methodology). CPUE data were also obtained from the commercial *C. maenas* fishery operating over the mussel beds. To establish the reliability of CPUE as a predictor of relative abundance, the influence of abundance and feeding rates on the CPUE of *C. maenas* was determined. CPUE was predicted based on feeding rates at the mean monthly temperature in the Menai Strait using the function $y = -0.492t^2 + 12.856t - 53.12$ (where t is temperature, °C).

CPUE and temperature showed marked seasonal variation (Figure 2.28). There was no significant correlation between mean monthly seawater temperature and *C. maenas* abundance ($y = 467.1x + 438$, $R^2 = 0.229$, $F_{1,11} = 3.2635$, $p = 0.098$). However, there was a significant linear correlation between temperature and the abundance measured two months earlier ($1018.6x + 5748.5$, $R^2 = 0.828$, $F_{1,11} = 53.101$, $p<0.0001$; Figure 2.29), indicating that crabs may be responding to the change in temperature, rather than absolute temperature, or to some other cue.

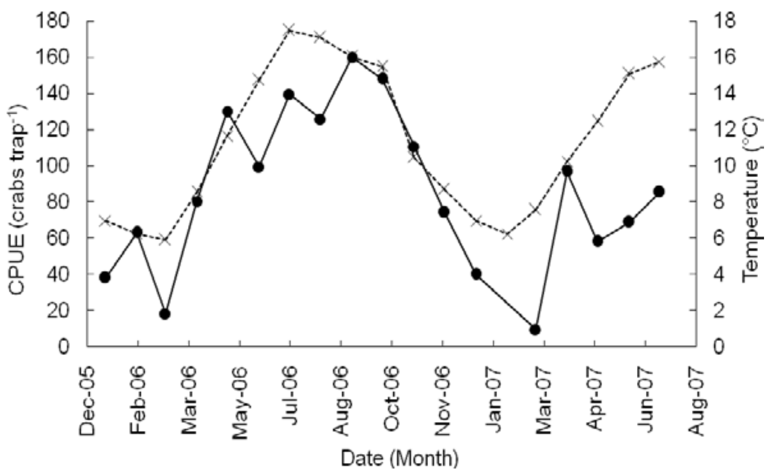

Figure 2.28. Mean number of *Carcinus maenas* caught per trap per day on cultivated mussel beds (•), and mean monthly seawater temperature (×) in the Menai Strait during 2006 and 2007.

There is a significant relationship between indices of feeding rates and CPUE ($F_{1,10} = 20.056$, $R^2 = 0.667$, $p = 0.001$; Figure 2.29). Changes in abundance based on video surveys did not match CPUE estimates of relative abundance, with the rate of change in abundance paralleling that of CPUE two months later. There was no significant relationship between abundance and CPUE, even when CPUE data were adjusted to account for variations in feeding rates with temperature. Therefore, in this case, CPUE appears to be determined largely by feeding rates. Migration may be initiated by maximum and minimum photoperiod. Unlike temperature, day-length did show a significant correlation to *C. maenas* abundance without any lag ($y = 802.808 + -396.353x + 64.552x^2$; $R^2 = 0.805$, $F_{2,12} = 24.842$, $p<0.0001$). It is important that CPUE data are validated for other crustacean species with fisheries- and trap-independent data. In particular, rising seawater temperature may result in increased catches which could be interpreted, incorrectly, as an increase in abundance unless CPUE data are validated with trap-independent data.

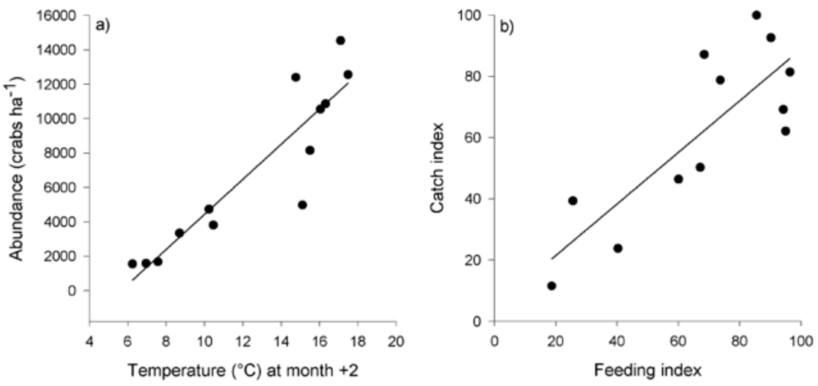

Figure 2.29. Correlation between a) temperature two months after abundance was measured and b) indices of feeding rate and catch per unit effort.

2.3 In response to ToR d)

ToR d) Review and compare assessment methods for crab fisheries and the associated data requirements

2.3.1 Background

As a basis for discussion of the range of stock assessment methods used for crabs, Mike Smith (UK) presented a brief review of assessment methods that have been used for crabs based largely on Smith and Addison (2003) and summarised in Table 2.10. An example of a typical stock assessment for brown and velvet crab undertaken in Shetland , UK is then provided in section 2.3.3.

2.3.2 Review of assessment methodology

Crabs are particularly difficult to assess and many of the assumptions of assessment methods are violated. Like many invertebrates, crabs have highly spatially-structured and patchy distributions. Crabs show sufficient directional movements to violate steady state assumptions, but are also sufficiently sedentary that there is marked spatial structure in stock distribution and demography. The fishery is largely through static gear and can also be highly spatially structured, so assumptions that all animals are equally vulnerable to the gear are frequently broken. There are also large changes in crab catchability both seasonally and by sex that can make constant catchability assumptions unsuitable. These factors all make analytical assessment difficult, and if high quality data are available, empirical and relative approaches to assessment and management may be appropriate. A list of desirable data that could form the basis for indicator based assessments was suggested (Table 2.9). However, analytical assessments may be useful in some instances especially where there are long time series of data and good confidence in the quality of the data. Exploratory modelling approaches may also be useful to investigate the theoretical responses of stocks and fisheries to different management options.

Table 2.9. Desirable data for indicator based assessments

Individual CPUE data (on a daily basis)
Different CPUE indices for different parts of the fishery
Fishery independent CPUE series
Replication of indices
Standardised CPUE to take account of spatial, temporal, vessel, soak time, … effects
Data reflecting different aspects of the stock/fishery (e.g. length frequency data)
Recruitment index

The Group discussed standardisation of catch rate data and whether they should be standardised in a particular way. It was noted that the requirements for standardisation would vary with the data and need to be considered case by case. Initially raw data should be inspected in disaggregated form to identify systematic variability between factors that might need standardisation. For snow crab the data are inspected and clearly erroneous points removed on the basis of checks against catch rates, pot numbers, engine power, etc. There is no need to standardise seasonally because the fishery occurs over a short season.

Although it is possible to get very detailed spatial catch data, this will probably need to be aggregated at some point and deciding on appropriate spatial scales for standardisation and aggregation can be difficult. It was noted that very complex data collection systems may fail at the fisherman reporting or data entry levels and too much data increases handling and processing costs. A degree of compromise and pragmatism is therefore required. At present most commercial catch and effort data are captured using paper logbooks and, in many cases, data are of variable quality, some are excellent but many may be poor. Various electronic data capture systems are being piloted for small sub-sections of fishing fleets and these often involve the collection of high definition spatial information. In France, sensors have been fitted to some pots recording environmental data such as depth, salinity and temperature, while in Scotland GPS data loggers recording at high frequency and reporting using SMS provided clear information of fishing activity and thereby pot locations on a string by string scale. The group noted that electronic data capture systems can reduce input errors and costs and envisaged increasing use of such systems in future. It was also noted that more expensive equipment may require less calibration and prove more reliable thus proving cheaper in the long-term. Disadvantages noted with electronic data capture systems included insufficient weather proofing for use on small vessels in some instances and sometimes resistance to VMS systems by the fishing industry.

Length frequency data from landings can provide an alternative index of exploitation, while survey or catch length distributions provide different information reflecting the population. Self-sampling for length by fishermen requires validity checks although these may be carried out on a relatively small sub-sample.

Data on recruitment would provide a very useful indicator and this could potentially be derived from length frequency data from catches or surveys. There is an issue of time for fishermen involved in self-sampling and observers may be required to provide independent checks. The use of alternative gears would need to be considered to select for smaller individuals and the issue of what constitutes (pre-) recruits given variable minimum landing sizes (MLS) and the uncertainties in growth rates associated with crustaceans. Surveys of the intertidal might provide some information on juvenile abundance, but previous work in France suggested this approach was not effective.

The WG decided that next year it would attempt to carry out preliminary indicator based assessments for edible crab stock complexes in the English Channel, Celtic Sea and Bay of Biscay and on the Malin shelf. Stock coordinators from the countries with exploiting fisheries would coordinate data compilation and the group would break into sub-groups to discuss individual crab stocks. The Group would also ask through ICES for (by-) catch data, including landings of crab claws, to be made available from other countries with demersal fisheries in these areas, including Belgium and Spain. Feedback from Industry possibly at local scales could be obtained to see if there was consensus on fishery status. Assessments would not necessarily be analytical, but would aim to evaluate whether and how the Group can comment on the status of crab stocks. Consideration of time series within long-term confidence intervals and relative performance of indicators could be used. The Group would not dictate what national sampling programmes should be carried out, but would coordinate the compilation of available data to the stock/fishery level and the Group would not provide management advice unless asked.

The Canadian experience was that 'traffic light approaches' (TL) may tend to oversimplify and that Industry may interpret amber signals as a warning of future restrictions and that indicator-based approaches were better. The Canadian snow crab fishery uses an indicator-based approach with TAC adjustments made on the basis of declines in CPUE trends. TAC changes were broadly linearly related to CPUE trends, but tended to move in steps of 15% or more because smaller steps were thought to be ineffective. Under-reacting to increases in crab abundance could lead to wastage of resource potential and a build up of senescent crab. This fishery has a short season and management also offered incentives in the form of extra quota to exit the fishery early.

The Group considered that an indicator approach might therefore be preferable to a TL approach and also considered that a gap analysis on the assessment data needs would be useful.

Table 2.10. Summary of presentation on assessment methods used for crabs

Method	Rationale	Output	Data needs	Comments
Length converted catch curves	Slope of downward limb of log differences in catch divided by time interval is plotted against age. Assumes population at equilibrium.	Total mortality (Z)	Catch or survey length distributions and growth rates	Tractable method, readily providing confidence intervals. Equilibrium assumptions likely to be broken and it is sensitive to growth parameters. Application to crabs: Cancer pagurus Cefas, unpublished
Length cohort analysis (LCA)	Starts with assumption of exploitation rate for the last length class and works backwards, numerically estimating numbers and fishing mortality for each length class in turn. Assumes population at equilibrium.	Population numbers and fishing mortality at length	Total landings length distribution and growth rates. Assumptions for terminal exploitation rate and natural mortality.	Relatively simple method, provides estimates of F and stock numbers and the output is readily useable for length based per recruit analyses. Steady state assumptions are likely to be broken and it is sensitive to parameters. Application to crab: Cancer pagurus Addison & Bennett, 1992; ICES, 2006
Biomass dynamics models - Schaefer, Fox, Pella-Tomlinson and others	Biomass is a function of previous biomass minus the catch. Time series of abundance indices are used to numerically fit the model usually assuming direct proportionality with a constant catchability coefficient.	Estimation of carrying capacity, and population rate of growth. Time series of biomass estimates, exploitation rates and estimated fishing effort. Maximum sustainable yield and stock collapse reference points.	Time series of catch data and abundance indices that may be commercial CPUE or survey indices.	Relatively simple dynamic models that can be modified to include extra factors (environment, predators). Useful output of time series of biomass and exploitation levels and reference points. However, often difficult to obtain unique and realistic fits due to confounding between parameters, especially if contrast in the data is weak, which is often the case for crabs. Aggregate dynamics do not permit evaluation of length structured effects (e.g. MLS). Application to crabs: Cancer pagurus ICES (1998), unsuccessful; in Bayesian framework (www.poorfish.eu), Laurans & Smith, 2007.

Closed system depletion methods – Leslie & Davis, DeLury and Index removal	These methods examine the effect of measured removals of fish (catch), or measured episodes of fishing effort, on abundance, usually an index such as CPUE. The system is assumed closed – no migration, recruitment or natural mortality.	Provides snapshot estimates of population size in the experimental area and by using total catch data estimation of exploitation rate	Quantitative information on sequential removals (catch) for Leslie method, or sequential fishing effort for the DeLury method, and and abundance index (CPUE) series taken during the successive fishing episodes.	Simple model and a powerful way to estimate abundance in small areas experimentally or where a very intense short season fishery is in place. However, closed system assumptions may be broken and bias or variation in q may cause problems. These methods also require a significant fishing effect relative to the population.Application to crabs: Chionoecetes opilio Chen *et al.* (1998); Dawe *et al.* 1993
Method	**Rationale**	**Output**	**Data needs**	**Comments**
Change in ratio (CIR)	Explores changes in the ratio of distinct (e.g. marked or recognisable) components of the population in response to known removals. Assumes a closed system or that any factors affecting the population population (e.g. movement or natural mortality) are same for both components. Relative catchability of the two components is assumed to be constant, although actual catchability can change between episodes.	Provides snapshot estimates of population size and exploitation rate.	Quantitative information on the removals by distinct population component. Prior and post fishing season surveys are usually used to determine ratios of the distinct population components.	This simple method provides a powerful means of estimating abundance and exploitation rate given marked or otherwise distinguishable components to the population. However, closed system assumptions may be broken, the method requires a significant fishing effect relative to the population and effective surveys before and after fishing. Application to crabs: Chionoecetes opilio (Dawe *et al.*, 1993; Chen *et al.*, 1998)

Open system depletion methods – Two stage DeLury or catch survey analysis (CSA)	Generalised depletion method incorporating natural mortality and recruitment. Abundance indices are considered proportional to adult stock numbers and recruitment with constant catchability coefficients.	Provides a time series of population estimates and exploitation rates.	Data needs for CSA are catch data, survey abundance indices, covering both pre-recruits and exploited ages, and an estimate or assumption of natural mortality.	Open system depletion methods similar to production models, but deal in numbers. The method is robust to different population dynamics and stage structuring may permit some (limited) evaluation of length or age effects. However, the model is sensitive to definition of pre-recruit and fully recruited stages and the relative weightings given to these and requires survey information of multiple stages.Application to crabs: Paralithodes camtschaticus (Collie & Kruse, 1998)
Dynamic length structured models	Fully flexible length structured population models fitted dynamically through time. Time steps may be annual or modified top take account of biological factors. Minimisation can be based on observed and expected catch numbers and/or take other data into account.	Provides fully length structured times series of population outputs.	Data needs depend on the complexity of the model, but are likely to include time series of length structured catch data as a minimum, parameters for the growth model used and natural mortality.	Provide a means of explicitly modelling moult-increment growth processes of Crustacea and incorporating time series of length structured data. Biologically realistic. Fully size structured. Minimisation on catch numbers at length and other data can be included. However, the models are generally complex and therefore may not be transparent. They usually have lots of parameters (or assumptions) and unless some of these can be determined out with the model fitting, there may be a tendency for parameter confounding. Application to crabs: Chionoecetes opilio & Paralithodes camtschaticus, Zheng *et al.*, 1995; 1996; 1998

2.3.3 Shetland Crab Assessments

In addition to the analysis and interpretation of trends in landings per unit effort from fishermen's logbook data (see section 2.2.2.2.2), assessment of the brown and velvet crab fisheries from around Shetland is carried out using length cohort analysis (Leslie *et al.,* 2008). Data collection is carried out throughout the year through commercial sampling, survey work and research projects to produce detailed length frequency distributions, which are analysed along with landings data from logbook returns. For both brown crabs and velvet crabs model input parameters for growth and mortality specific to the Shetland Stocks are available (Tallack, 2002). In order to provide comparisons for the management organisation, analysis using further input parameters is provided, along with the potential long term implications of increasing the minimum landing size.

Brown crab

The data used for assessments and the input parameters for the LCA and their sources are shown in Table 2.11. The results of the LCA analyses are shown in Figure 2.30.

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

Input parameter	Female	Male	Data source
Size frequency data			Commercial fishing (Years 2001 to 2006)
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)

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 (Figure 2.30). The long term predictions for females suggest that changes in fishing effort could have some influence on landings, with a predicted increase in landings of 11.6% associated with a 30% increase in effort. A 30% decrease in effort, is predicted to result in a 16.4% increase in the total stock biomass in the long term. 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 and biomass with this change in minimum landing size (Figure 2.30).

The long term predictions of yield and biomass for male brown crabs (Figure 2.30) 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 below the maximum yield per recruit, however, the fishery appears to be moving closer to the MSY and substantial increases in fishing effort would not translate into proportionately higher landings. It is predicted that with an increase in fishing effort of 40%, the subsequent long term increase in landings would be 6.1%. 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 changes in fishing effort (Figure 2.30).

Velvet Crab

The input parameters for the LCA and their sources are shown in Table 2.12. The results of the LCA analyses are displayed in Figure 2.31.

Table 2.12. Input data for velvet crab length cohort analysis.

Input parameter	Female	Male	Data source
Size frequency data			Commercial fishing & survey work (2007)
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.

At current levels of fishing effort 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 2.31). The yield per recruit curve, however, shows that 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 3.7% in landings in the long term. This would result in a corresponding decrease of 4.7% in the biomass of the stock. 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 2.31).

The yield per recruit curves produced for male velvets showed only slight differences from those produced for females. At the current level of fishing effort the fishery is predicted to be operating below the maximum yield per recruit. 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 2.31). A reduction in fishing effort by 20% forecasts an increase in the total biomass of 6.6% and a decrease in landings of 6.4%. Changing the minimum landing size to 75 mm was shown to have little effect at current levels of fishing effort (Figure 2.31). The largest difference seen in the long term predictions of yield was through significant changes in fishing effort.

The velvet 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.

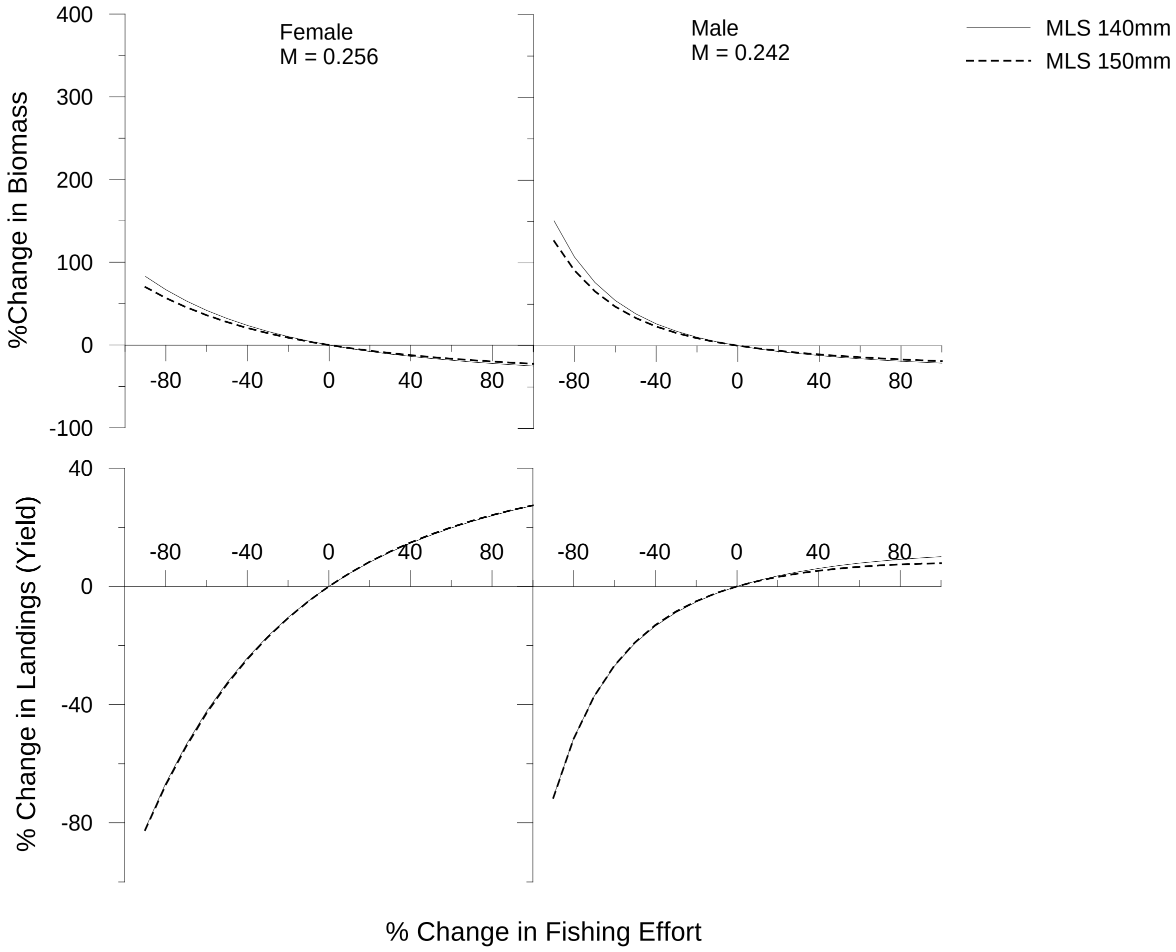

Figure 2.30. Long term predictions of yield and biomass of female and male brown crab stocks with changing fishing effort at the current MLS of 140 mm, and at a MLS of 150 mm, using the estimated natural mortality *M* = 0.256 for females and 0.242 for males.

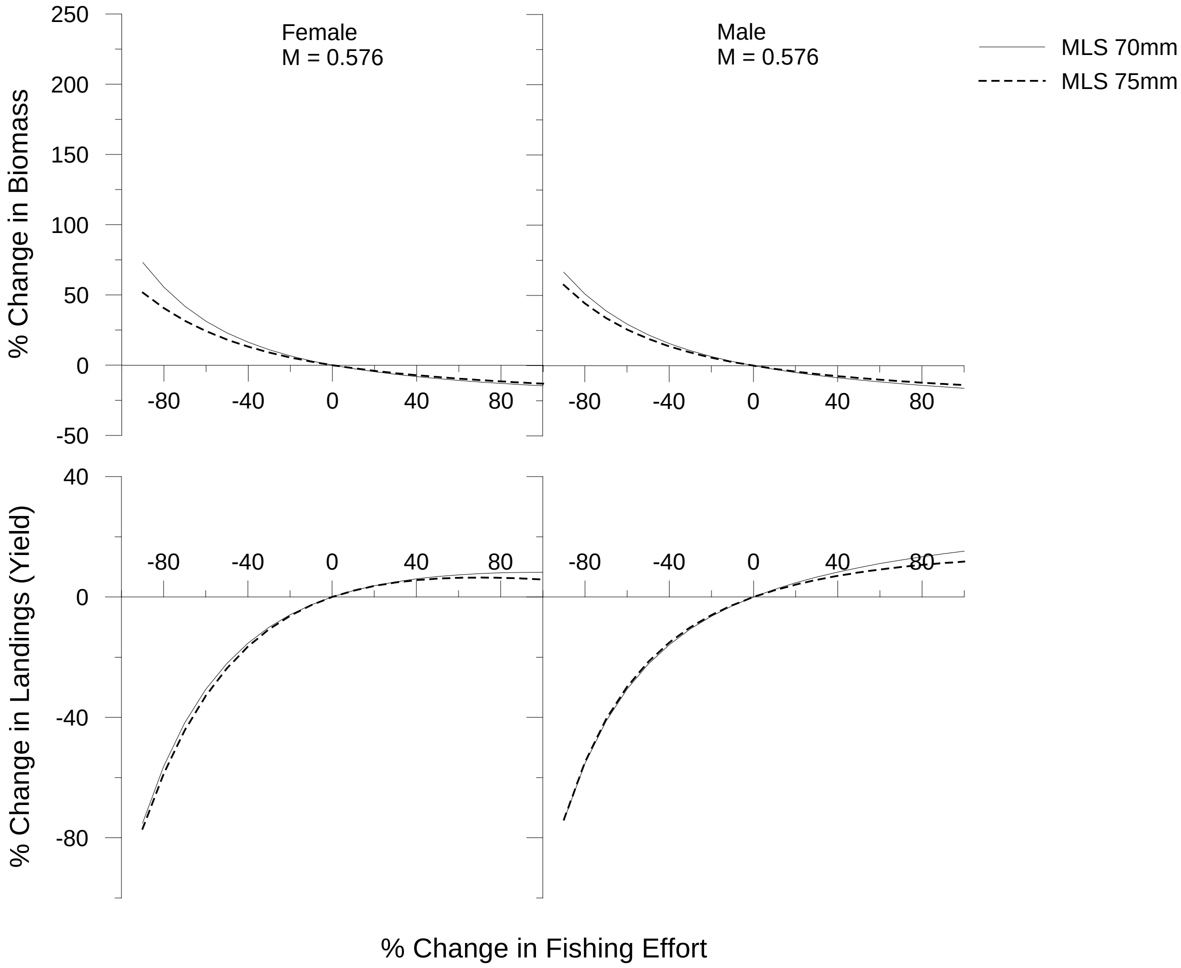

Figure 2.31. Long term predictions of yield and biomass of female velvet stocks with changing fishing effort at the current MLS of 70 mm, and at a MLS of 75 mm, using the estimated natural mortality *M* = 0.576.

2.4 In response to ToR e)

ToR e) Review biological information that is required for providing standardised indices and for analytical assessments.

2.4.1 Background

The long term objective of the WG is to provide an assessment of the status of the crab stocks within the ICES area and, if necessary, provide management advice. At present it is clear that there are significant gaps in the biological information that is required for providing standardised indices and for analytical assessments. The WG agreed that it should continue to review the range of biological studies that are ongoing within the various fisheries (examples are described below), but that it should also systematically review the biological parameters, such as growth, natural mortality, length-weight, migration, and maturity and fecundity, that are required for assessments, and their spatial variability.

2.4.2 Lot 1: Joint data collection between the fishing sector and the scientific community in Western Waters.

One of the case studies of the EU Lot 1 project is a pilot study of self sampling and data collection techniques in the brown crab fisheries in ICES areas VI and VII. Partners in this project led by Cefas (England) include IFREMER (France), FRS (Scotland)

and BIM (Ireland) and industry partners from these countries. The project will focus on ways in which to collect important fisheries information. This will include the use of GPS information (loggers and VMS positional data) to map fishing effort. The recording of catch information from the fisheries will be trialled with the design and implementation of more effective log books (paper and electronic). It is also envisaged that scientists and industry will work together to develop methods of self-sampling of the catch to gain better information on discards and by-catch and length frequency distributions of the catch.

2.4.3 Tagging projects on brown crab (*Cancer pagurus*)

2.4.3.1 Scotland

In Scotland FRS are undertaking a brown crab tagging project which is funded by the Scottish Industry Science Partnership (SISP) and involves the Scottish Fishermen's Federation (SFF) and two fishermen's associations. The tagging work is due to commence in the summer of 2008 and will focus on the interactions between the inshore and offshore crab populations to the north of Scotland. A similar tagging project is currently being carried out by the NAFC focusing on brown crab populations around Shetland (see below). A similar tagging project is also being proposed around Orkney. The spatial coverage of these projects will be complementary and should provided information on much of the northern populations of brown crab in Scotland.

2.4.3.2 Shetland Isles

Shellfish stocks in the waters around Shetland are managed using a regulating order. This provides the Shetland Shellfish Management Organisation (SSMO) with the power to manage the stocks through a licensed fishery within six miles. Under the regulating order fishermen submit weekly logsheets detailing their catch and effort, and area fished. The NAFC Marine Centre compiles this information along with data collected from the fishery in order to carry out stock assessments. Although fishing within six miles is well documented, there is often quite substantial fishing effort from large vivier crabbers outwith this area. It is known that the brown or edible crab (*Cancer pagurus*) can travel relatively large distances (e.g. 208.2 km, Tallack 2002) and that females undergo migrations relative to their reproductive status. It is therefore important for the assessment and management of local fisheries to have a better understanding of the stock distribution in order to determine the potential effect of effort outwith the management area. A tagging study was therefore set up to determine the movements of crabs off the west coast of Shetland.

The tagging programme involved tagging 2000 brown crabs of both sexes, and both above and below the minimum landing size of 140 mm. The tagging was carried out to the west of Shetland from January to April 2008 both inside and outside the six mile limit. To date a total of 45 recaptures have been made with 38 tagged crabs being caught, the majority of which have been female. The distances travelled have ranged from around 3 to 20 nautical miles. It is hoped that these, and further returns from fishermen will provide information on the distribution of the stocks that will better inform the management process.

2.4.3.3 Tagging crabs with conventional and data storage tags in UK

Cefas is currently carrying out a Defra funded R & D programme, tagging edible crabs (*Cancer pagurus*) in the English Channel. It has been 30 years or more since the last studies of edible crab growth and movements in the area, and since that time there have been big increases in the extent of, and landings from, the edible crab fisheries in the area as well as large scale extraction of aggregate in certain areas and the possibility of climate change. It was therefore considered pertinent to investigate aspects of this stock to improve knowledge of movements (and thereby stock structure), growth and exploitation of crabs in these fisheries.

Approximately 15,000 crabs will be tagged over the 3 year period (2007-2009) using Floy FD-94, ⅜" mono SHD, double T-bar tags. Tagging will be carried out by arrangement with commercial crab potters at sites both in the Channel and along the north Cornwall coast in the early summer and late summer/autumn periods. An extensive and comprehensive publicity programme, both in England and Wales and abroad, preceded the project and is ongoing during the course of the project. As an incentive to report recaptures, all returns in each year of tagging, which provide full details of the recapture and size of the crab, are eligible for a £6 reward and will be entered in an annual lottery with a single prize of £500. In addition there is to be a final lottery for all returns at the end of the project with a further £500 prize. Reporting details of tagged crabs can be achieved by a range of routes including a dedicated email address and telephone number, links via the Cefas website, in person to local fisheries offices or by normal mail.

To minimise damage associated with the tagging procedure the tagging gun was modified to reduce penetration of internal tissues of the crab as much as possible and was regularly disinfected in 100% ethanol to reduce risk of infection. Release data were captured using a hand-held mini-computer with onboard GPS, allowing precise recording of the release position of every crab tagged and facilitating the accurate transfer of information to the tagging database. The precision of return data is dependent on the person catching and reporting the crab and unlikely to match the high quality of release data.

Aquarium experiments are being carried out to investigate double T-bar tag retention. These experiments also provide information on survival and growth as well as observations on behaviour and spawning. However, the Cefas tank facilities are not ideal for holding crabs and survival rates are unlikely to reflect those of tagged crabs returned to the wild.

In addition to conventional tagging (with T-bar tags) up to 100 crabs will be fitted with electronic Cefas G5 long-life, data-storage tags (DST's) and released. These have the potential to record temperature, pressure and movement for up to a year and complement the conventional tagging data by allowing a fine scale, detailed picture of recaptured crabs' movements and activity patterns to be built up over their time at liberty. DSTs will be attached to around 40 mature, new-shell (unlikely to moult) females in the eastern Channel in autumn 2008 and the remainder will be fitted to suitable male and female crabs in the western Channel in both late spring and autumn 2009. Aquarium experiments to evaluate options for attaching DST's to crab carapaces suggested that a combination of super-glue for quick adhesion and an epoxy-resin, water resistant paste ("Mr Sticky®") for the long term was effective, while neither were particularly successful when used in isolation.

Results to date

Aquarium trials to evaluate retention have being performed on a sequential basis using 24 crabs in each trial (16 + 8 controls) because of cost and space limitations. In the first trial (July 2007) 6 tags were shed over 200 days; 4 tagged crabs moulted without tag loss (but on death 2 of these were found to have been lost subsequently). All but one tagged crab had died after 340 days (95%) and 62% of the controls. Mortality rates of tagged crabs were higher than controls initially, but were similar to controls after around 100 days. It is thought that a combination of high water temperature (>17ºC), low salinity and possible infection in combination with the stress of handling and tagging was the cause of the high initial mortality rates and mortality is likely to be lower under field conditions. The second trial was over-winter and had better sterile tagging techniques as well as using a smaller version of the tag in order to reduce tagging mortality. When the trial was terminated after 129 days 85% of small tags were retained but 100% of the large. Mortality was reduced with none up to 48 days and then similar levels (ca. 40%) in both (large and small tags) treatment and control crabs thereafter. With a non-significant statistical difference for crab survival between large and small tags, it was decided to use the larger tags in the field for greater visibility to the finders.

2436 crabs were tagged and released in October 2007 at three locations; Bullock Bank, Hastings Shingle Bank and the Sovereign Shoals, all of which are commercial crab fishing grounds in the eastern Channel. In November a further 1733 crabs were tagged off Portland Bill, Dorset in the western Channel. The sex ratio of tagged crabs was around 3.5F : 1M in all locations. Sex ratios of returns show reduced numbers of females probably reflecting that returns have been made over the spawning period when females were less likely to be caught. The recapture rates in March 2008 were 19% in the eastern Channel, all in the general areas of release and 11.5% in the west. Six long-distance movements to the west took place from Portland, the furthest, 97 km in 67 days and the fastest 94 km in 45 days, both mature females. Generally the pattern of movement of both females and males in both areas was westwards and more marked for females.

In 2008 tagging is planned off Lands End, Cornwall (extreme western Channel) and on the main fishing grounds south of Devon in June to look at the movement of post-hatching females, which are reported by fishermen to move from west to east. Later in the year tagging will be done on the west and north Cornwall grounds between Lands End and Trevose head in August/September. 40 DST's attached to mature, new-shell females will be deployed in the eastern Channel in late summer. Aquarium trials will be continued.

In 2009 tagging is planned on the main fishing grounds, in the western Channel including mid-Channel if possible, both in spring and late summer/early autumn. This will include the use of up to 60 more DST's deployed on both male and female crabs.

Continued aquarium trials are also planned.

2.4.4 Spatial variability in velvet crab populations – a possible candidate for real time fisheries management

Recent data collection and feedback from fishermen have shown that there is variability in the patterns of moulting in populations of velvet crabs (*Necora puber*) around Shetland. This variability occurs both between years, and between areas. As a result of this, staggered closed seasons have been implemented to protect stocks during this vulnerable time. In recent years this has seen the west coast of Shetland closed to velvet crab fishing during July and August and the east coast area shut in September and October. However, variability in moulting has resulted in the closed seasons being ineffective, in some cases displacing effort from areas where crabs are hard-shelled to areas with a higher proportion of soft-shelled crabs. Previously, total closure of the fishery disrupted supply to the market, and presented an economic challenge to inshore fishermen who found it difficult to diversify locally to other species for the period of the closure.

During this project work is being carried out in order to determine the extent of variability in the velvet crab population, both spatially and temporally, and to determine the suitability of this fishery for real time closures during periods of moulting. Initial data collection on the presence of soft crabs within the Shetland fishery has shown that the closed season did not match the periods of moulting within the velvet crab population in 2007, resulting in displacement of fishing effort to areas with soft crabs. A successful method for the classification of soft crabs at sea has been identified, and this could be implemented to inform the management system so that closures can be synchronised with the moult cycle of the velvet crab. Further data collection is ongoing to provide greater detail to the Shetland Management Organisation (SSMO) in order for them to assess the suitability of this method for informing real time closures.

This project is funded by DEFRA Fisheries Challenge Fund and SSMO.

2.4.5 Biological information for snow crab – ongoing research in Greenland

This research proposes to study some aspects of the reproductive potential of snow crab in the coastal waters of West Greenland. Fisheries exploited and non-exploited stocks will be compared as well as populations in hydrographical systems subject to different temperature regimes. Various life history traits will be examined and related to reproductive potential at three study sites along a latitudinal gradient: Disko Bay (north), Sisimiut (middle) and Nuuk (south). The goals of this project are to better understand the reproductive potential of the snow crab, as it relates to temperature conditions and fishing pressure, and to provide essential baseline information for adaptive management and conservation strategies. What is unique about this study is the possibility of investigating life history traits of an unexploited population of snow crab. The effects of temperature and exploitation on snow crab population dynamics and – especially – on reproductive potential are multifaceted, complex and possibly synergistic.

2.5 In response to ToR f)

ToR f) Assess and report on the effects of disease on crab fisheries, and produce a manual for the fishing industry on *Hematodinium* infection of crabs including bio-security

2.5.1 Review of crab diseases

Crabs are susceptible to a whole range of diseases. A review of diseases in brown crabs (*Cancer pagurus*) in UK waters described two viruses, one found in wild juvenile crabs in the English Channel, and one found in an experimental laboratory system in France. Bacterial infections cause both shell disease and systemic infections through infections of the haemolymph, and fungal infections are a big problem in crustacean aquaculture. *Hematodinium* spp. can be found at high prevalence and can cause mortality directly or indirectly particularly in the winter, but little is known about transmission from host to host. Other protistans include *Enterospera canceri* which is found in the hepatopancreas and which was found at low levels in the English Channel, and *Paramartelia canceri* which causes tremoring in crabs and which has a prevalence of around 5% in *Cancer pagurus* in the English Channel. Metazoan infections include *Paragonimus westermani* which encysts itself within the carapace and tissue of Chinese mitten crabs causing lung fluke in humans but not yet found in the Thames population of mitten crabs, and *Sacculina*, a parasitic barnacle which causes parasitic castration.

The challenge with all these infectious agents is to gain an understanding of how disease agents regulate populations and at what life history stage.

There is a new European Union Fish Health Directive (2006/88/EC) which lists three crustacean diseases which must be reported– white spot disease (WSD), which is highly pathogenic and will cross between crustacean species with ease, Taura Syndrome (TS), and yellow head disease (YHD). Until now disease in crustaceans went unrecorded. Now the competent authority (e.g. Government Department) must investigate and report any designated diseases to the National Reference Laboratory. The national laboratories are then overseen in terms of diagnostic tests etc. by the European Community Reference Laboratory (CRL) based in Weymouth, England whose aim is to improve the bio-security status of Europe in terms of exotic crustacean pathogens.

2.5.2 *Hematodinium*

Hematodinium spp. are found in many different crustacean species, and the WG discussed monitoring programmes for *Hematodinium* in various countries. In North America there is an extensive monitoring programme for infections of snow crabs where it causes Bitter Crab Disease (BCD), and can have a significant effect on the economics of the fishery. In Canada, prevalence of up to 60% has been observed in some areas, with epidemics in 2000, which was primarily in small females, and in 2005 in both sexes. Little is known about why the patterns of infection were so different in the two epidemics. A programme of tagging both infected and non-infected crabs produced lower catch rates of infected crabs suggesting higher mortalities. Prevalence was generally similar across size ranges. There was no movement of infected animals in comparison with healthy ones, and very low survival rates of infected crabs after 185 days, although one or two lived for 240 days. This type of monitoring and research is essential if we are to understand the real implications of disease on crab population dynamics.

The prevalence of *Hematodinium spp*. and occurrence of Bitter Crab Disease in Greenland waters is still unknown. Monitoring in West Greenland in 2003 and 2004 showed that BCD was widely distributed from 66–70 degrees N and offshore 60 degrees W. Prevalence rates were low (average 2%) but this may be because the survey looked only at visual signs such as milky white texture, and PCR indicated that there may be infection rates of up to 80% in inshore areas e.g. fiords. Improved detection rates are clearly needed.

There is very little work on *Hematodinium* in Europe, primarily due to a lack of funding probably because BCD is not seen as a human health problem, even if it can affect the market for crabs, but perhaps also because there are more problems in Europe with moult state and other mortalities to create significant concerns about mortality/poor quality due to disease. Some monitoring has occurred in Ireland where concern has been expressed about crab being used as whelk bait with consequent concerns about the spread of disease. There was no obvious seasonal pattern in prevalence, but infection **intensity** does seem to follow a seasonal pattern. It is likely that a drop in temperature brings on the higher intensity. The highest prevalence does not coincide with a period of whelk fishing, and was much higher in smaller *Cancer pagurus* even though smaller animals are not sampled adequately. In England, there are proposals to monitor infection rates in crabs as part of a tagging and recapture programme in south west England.

In general estimating prevalence rates of *Hematodinium* in crabs is complicated by methodology, and until extensive monitoring programmes are introduced, we will not be able to assess the impact of this disease on the population dynamics of the host crabs.

At last year's WG (ICES, 2007), it was agreed that a leaflet would be produced to educate the fishing industry about the potential problem of *Hematodinium* in European crab fisheries, and to provide advice to the industry on best practice in dealing with infected animals. A draft leaflet was produced, but following discussions on the lack of knowledge of prevalence rates and regulations about how fishermen should dispose of infected crabs brought ashore (the best way to reduce transmission rates), the WG decided to postpone the circulation of any leaflet until more information had become available.

3 Election of Chair

At the end of 2008, the three year term of the current chair, Julian Addison, comes to an end. The Working Group unanimously re-elected Julian Addison (UK) to serve a further three year term from 1 January 2009.

4 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. In particular the WG **recommended** that it should meet for an extra day in 2009 to collate fisheries data from the various national programmes for the Western English Channel and Malin stocks of *Cancer pagurus* that are exploited by two or more Member States.

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 Scalloway, Shetland, UK, 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.

WGCRAB will report by 1 July 2009 for the attention of the LRC and ACOM.

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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 Scalloway, Shetland, UK, 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.

WGCRAB will report by 1 July 2009 for the attention of the Living Resources Committee.

Supporting Information

Priority:	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 effort. Knowledge of the population dynamics of these species is also weak. These stocks may be at risk from over-fishing. 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 action plan:	a) Although crab stocks are heavily fished and there is no effort control in European fisheries, catch rates appear stable or are increasing. In part this increase in catch rates may be due to an expansion of fishing grounds and an increased understanding of stock structure will be necessary 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. [Action Plan Number 1.2.1]. b) The European *Cancer*, *Maja* and *Paralithodes* stocks, some of the Kamchatka crab (*Paralithodes camtschaticus)* 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. In addition these fisheries are becoming more international in nature and more highly capitalised with the expansion of effort to offshore grounds. [Action Plan Number 1.2.2]. c) There is a high reliance on CPUE data in the assessment of European crab fisheries and this is likely to remain the case in the medium term. Size frequency data are also collected in a number of fisheries. Small scale temporal and spatial variability in size frequency data may affect the estimates of fishing mortality in analytical assessments. Methods of aggregation of size frequency data are therefore important. In Canada snow crab are assessed by trawl and pot surveys. Longer and better quality time series of data and automated methods for acquisition of CPUE data are becoming available. These data are reliable indicators of changes in stock abundance. More international collaboration and standardisation of methods for monitoring and assessment

	will be necessary given the increasing trans-national distribution of crab fishing. [Action Plan Number 1.2.2]. d) A wide range of stock assessment methodology is currently used in crab fisheries from simple indicator-based approaches through conventional size-based assessment methods to Bayesian approaches. The data requirements associated with each type of methodology need to be reviewed as the first step in providing information on stock status for the important crab fisheries in the ICES area. [Action Plan Number 1.2.2]. e) 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. [Action Plan Numbers 1.2.1, 1.6, 2.13, 3.16]. f) 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. Additional members working on other *Cancer* and King crab species in particular and specialists in resource modelling of fisheries data should be invited into the Group in order to deliver the terms of reference. Comparison of *Cancer pagurus* with *C. borealis* and *C. irroratus* on the east and west Atlantic may be informative.
Secretariat facilities:	None.
Financial:	No financial implications.
Linkages to advisory committees:	None.
Linkages to other committees or groups:	Resource Management Committee.
Linkages to other organizations:	None.
Secretariat marginal cost share:	ICES 100%