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7–10 June 2011

ICES Headquarters, Copenhagen, Denmark

International Council for the Exploration of the Sea

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Executive summary

The Working Group on the Biology and Life History of Crabs met at ICES Headquarters in Copenhagen, Denmark, 7–10 June 2011 with Jan H. Sundet as chair. The meeting was attended by 8 participants from 5 countries; Canada, Greenland, France, Norway and UK. Apologies were received from members from Ireland, Scotland and Sweden, and these will contribute to the report by correspondence.

The objectives of the meeting were to update and provide data and knowledge on landings, fisheries and biology of the important crab stocks in the ICES area. In addition, important objectives were to update and discuss the status of important crab stocks and introduced crab species, and assess the contribution of the WG to ICES Science Plan, according to the Terms of Reference f).

Data and results related to the different ToRs were presented orally, and two working group papers were submitted to the group. The first 1.5 days were spent with ToRs a) and b), continuing with ToR c) for the rest of day 2. There were no new estimates of natural mortality in crabs, but new results on size at maturity and fecundity in snow and red king crab were presented, in addition to results from a comprehensive tagging study of *Cancer pagurus* in the English Channel. ToR d), impact on ecosystem and distribution of introduced crab species, was highlighted through one presentation on the impact of the red king crab on benthos. The WG agreed not to discuss ToR e), diseases in crabs, due to lack of competence in this field among the participants present at the meeting. The group also suggested the existing ToR e) to be deleted from the list of ToRs in 2012 since there is another ICES Working Group dedicated to this issue (WGPDMO). In situations where diseases in crabs will be an aspect in the Group's topics or discussions, this could easily be included in ToR c) dealing with biological information required for assessment. The WG used half of day 3 to assess the WG's contribution to the ICES Science Plan and agreed to contribute on several of the sixteen topics listed.

The WG agreed to restructure the report slightly, in future, where the main highlights on each ToR dealt with in the meeting will be summarized in part one, and a more comprehensive report on each theme will be given as appendixes in a part two together with the Working Group Documents.

The Group agreed to highlight management approaches and biological reference points as subjects of the ToR b) at the next meeting in 2012, and to invite an expert in this field to initiate discussions. One major question is how biological reference points could be used both in crab stocks with and without fishery independent data and what is required for the different management approaches.

1 Introduction

The background history for the establishment of the WGCRAB is comprehensively described in the WGCRAB Report 2010, and will not be dealt with here.

It is a general agreement among the Group members that the annual meeting is of great value for each member, both to sum up the development in the different regional crab fisheries, and as a forum to discuss challenges in the management of the fisheries. WGCRAB is also a suitable arena for discussing particular issues on crab biology which is important since specialists working with the assessment on crabs are mostly single scientists in this field at the different national institutions. Despite only a few members attending the last meeting, all members of the Group are enthusiastic to continue the work within the Group through annual meetings.

2 Adoption of the agenda

The suggested agenda (see Annex 2) was adopted and rapporteurs were appointed in the beginning of the meeting.

3 Terms of reference 2011

The **Working Group on the Biology and Life History of Crabs** (WGCRAB), chaired by Jan H. Sundet, Norway, will meet at ICES Headquarters, Copenhagen, Denmark, 7–10 June 2011 to:

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

b) Evaluate assessments of the status of crab stocks, identify gaps in assessment programmes, and review the application of biological and management reference points for crab fisheries;

c) Review data on estimates of natural mortality and other biological information for crabs that are required for providing standardised indices and for analytical assessments;

d) Review the potential impact of introduced crab species and changes in the distribution of crab species in relation to climate change;

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

f) Assess the contribution of the WG to the ICES Science Plan.

4 Progress in relation to the Terms of Reference

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

ToR b: Evaluate assessments of the status of crab stocks, identify gaps in assessment programmes, and review the application of biological and management reference points for crab fisheries.

ToR c: Review data on estimates of natural mortality and other biological information for crabs that are required for providing standardised indices and for analytical assessments.

Introduction

The most recent data on several of the species and fisheries handled by the Group have already been reported in the WGCRAB report 2010, due to the late completion of this report (June 2011). In this report there are only progresses related to the Terms of Reference which are new and not reported earlier. One intends to avoid this in the future by arranging the WG meeting earlier in spring and to finish the report from the Group shortly after the meeting. At the meeting in 2010 the WG agreed on a series of summary spreadsheets, graphics and texts in which data should be presented as a standard (see Report of the Working Group on the Biology and Life History of Crabs 2010). Due to limited time at the WG meeting only the main commercially exploited crab species such as *Cancer pagurus*, snow crab (*Chionoecetes opilio*), red king crab (*Paralithodes camtschaticus*) and spider crab (*Maja brachydactyla*) are reported. The WG recognise that some important fisheries are not covered by this report because some countries were not represented at the WG meeting and no data have been provided. Nevertheless, the aim of the WG is that all commercially exploited crab stocks from all countries should be handled and reported by the WG.

5 *Cancer pagurus*

Assessment units

At the meeting in 2010 the WG agreed on several assessment units covering the fishing activities for the *Cancer pagurus* in northern Europe (Figure 5.1). In general, these units reflect how fishery data and assessment have been presented in previous WG reports. There are, however, still some unsettled boundaries between units where fishery from several countries takes place.

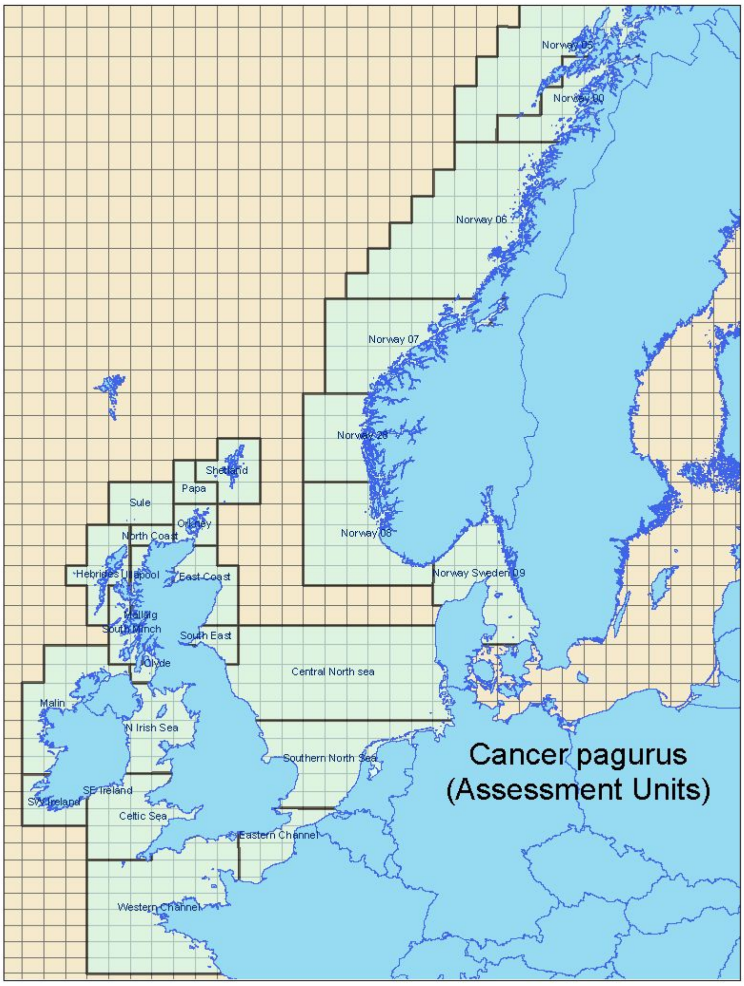

Figure 5.1. Assessment units for *Cancer pagurus* fished by vessels from UK, Ireland, France, Channel Islands, Norway and Sweden.

Data sources, assessment methods and management

Regarding *Cancer pagurus*, most basic data for assessment originate from landing statistics and logbooks in the fishery. Some countries or regions use observers onboard commercial fishing vessels and landings time-series are used as indicators in the assessment in some countries. Except for a few time limited studies (tag-recapture studies and larval studies) there are no known fishery independent data available for the stock assessment in any of the Cancer stocks studied.

Summary of assessments for edible crab (*Cancer pagurus*)

Summaries of the status and assessments of the various Cancer stocks were provided by England and Wales, Scotland, France, Shetland and Norwegian scientists (see table 5 A and B). These assessments summaries will be updated annually, although not all countries provides updated stock parameters each year. Table contents will therefore not necessary be different from one year to another.

Table 5 A. Stock summary for *Cancer pagurus* in England, Wales, France, Scotland and Norway.

Cancer pagurus

	Ireland	Scotland	England	France	Jersey	Norway
Number of stocks in which national fleet is active	4	12	6			1
Stock areas (cross reference to map)	Malin	Clyde, East Coast, Hebridies	Central North Sea			Whole Norwegian coast, Swedish border to Troms
	Celtic sea	Mallaig,North Coast, Orkney	Southern North Sea			
	Irish sea	Papa, Shetland,South East	Eastern Channel			
		South Minch,Sule Ullapool	Western Channel			
			Celtic Sea			
			Irish Sea			
Indicator						
Landings	1990-2010	1974-2010	1983-2010			1914-2011
Effort	1990-2010		1983-2010			2001-2010
LPUE	1990-2010		1985-2010			2001-2010
DPUE	1990-2010					2001-2010
Size frequency data	1990-2010	1974-2012	1983-2010			2001-2010
Others						
Analytical assessment methods						

LCA	No	Yes	Yes			No
Production		No				No
Change in ratio		No				No
Depletion methods		No				No
Others						No
Data sources						
Surveys						No
Larval	2002	No	1989, 1993			
Juvenile index /biomass	Index	No				
Adult index/biomass	Biomass	No				
Non target surveys	Scallop dredge	Scallop dredge (Data are currently being organised in a database)				
Commercial						
Observer/self reporting/reference fleet	Observer/ref fleet	Observer				Observer/ref fleet
Size frequency data	Yes	Yes	Yes			Yes
Logbooks	Yes	Yes (EU logbooks)	Yes			Yes
Tag returns	Yes	Yes				No
VMS	Yes	Yes(boats>15m)				No
Electronic logbooks	No	No				No
Others						
Biological parameters						

M	0,2	0,1	0.1-0.2			No
Growth data	k = 0.1-0.2	K_m=0.197 ; $Linf_m$=220; K_f=0.172 ; $Linf_f$=220;	k=0.2			No
Fecundity						No
Size at maturity	125 - 140	130-150				Females: L50 112 (mature), external roe: 130 mm or larger
Others		Terminal F=0.5				
Analytical assessment outputs						
Biomass	Yes	Yes				No
Spawning stock	No	No				No
Recruitment	No	No				No
Fishing mortality	Yes	Yes	Yes			No
Yield per recruit		Yes				

Table 5 B. Management measures table for *Cancer pagurus* in England, Wales, Scotland, France and Ireland.

Species	*Cancer pagurus*				Legislation and in particular local by laws are continually reviewed. The following may not be current.						
	Central North Sea	Southern North Sea	Eastern Channel	Western Channel	Celtic Sea	Irish Sea	Celtic Sea	Western Channel	Eastern Channel	Scotland	Shetland
Management measure	UK	UK	UK	UK	UK	UK	France	France	France	UK	UK
Licensing	MSAR/EU	MSAR/EU	MSAR/EU	MSAR/EU	MSAR/EU	MSAR/EU	yes	Yes	no	Yes	Yes
Limited Entry	Yes for <10m	Yes for <10m	Yes for <10m	Yes for <10m	Yes for <10m	Yes for <10m	no	Yes	no	Yes	Yes
Closed seasons	No	Generally No but regional ban on white footed crab Nov-June	No	No	No	No	no	no	no	No	No
Days at sea	No	No	No	No	?	No	no	no	no	No	No
Closed areas	No	No	No	No	Lundy	No	no	yes (very limited surface)	no	No	No
Others								no activity during high tide			
Minimum size	130mm CW (140mm	115 and 130mm	130mm in	Various/regional 140mm -	Various/regional	Various/ regional	140	140 and 130 under the 48° of latitude	140	130/140 mm (140 mm to	140

	north of 56N)	CW	Southern Bight and 140mm CW	150mm(CRH) 140-160mm (CRC)	130mm - 150mm(CRH) 130-160mm (CRC)	130mm - 140mm(CRH) 130-140mm (CRC)				the north of 56º N and 130 mm CW to the south of 56º N (except for the Firth of Forth))	
Maximum size	No	No	No	No	No	No	no	no	no	No	No
Berried female legislation	Yes	Yes	Yes	Yes	Yes	Yes	no	no	no	Yes	Yes
Soft crabs	Yes	Yes	Yes	Yes	Yes	Yes	no but release	no but release	no but release	Yes	Yes
Single sex fishery	No	No	No	No	No	No	no	no	no	No	No
Claws or parts	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears		increase of the claw fishery	mainly a claw fishery by the Boulogne-sur-Mer netters		No
Use as bait	Regional	Regional	No	No	No	No					No
Vessel size	Regional <12 and 16m inside 6nm	Regional <16 and 17m	Regional <14 and 17m	Regional <11, 15.24 and 16.46m	Regional <14, 15.2 and 16.46m and 21m	Regional <12, 13.7, 14, 15 and 21m	>18m	from 7 to 25 for potters and others métiers (netters and trawlers in some areas catch a lot crabs)	only 2 offshore potters (22 meters) during 2 months and 10-15 meters coastal potters and some netters as bycatch	No	<17m
Vessel power	No	No	No	No	No	No				No	No

VMS	>15m	>15m	>15m	>15m	>15m	>15m	yes	one part (25%)	one part (25%)	Yes	>15m
Log book returns	Yes	Yes	Yes	Yes	Yes	Yes	yes	yes	yes	Yes	Yes
Others								for little boat (national fishing sheet)	for little boat (national fishing sheet) and few information from the netter bycatches	No	
Trap limits	Yes	No	Regional	No	No	No	yes (1200)	yes (200 by fisherman and a maximum of 1200 by boat)	yes (200 by fisherman and a maximum of 1200 by boat)	No	No
Trap size	No	No	No	No	No	No	yes	yes	yes	No	No
Escape vents	Regional and gear specific Yes	Regional and gear specific Yes	Regional and gear specific Yes	Regional and gear specific Yes	Regional and gear specific Yes	Regional	no	on few pots	no	No	No
Biodegradable panels	No	No	No	No	No	No	no (very few lost)	no	no	No	No
Marked gear	Regional	Regional	Regional	Regional	Regional	Regional	no	in many areas parlour pots are forbidden		No	Yes

Landings of *Cancer pagurus*

Table 5 C. Landings (tonnes) of *Cancer pagurus* in England and Wales from 2000 to 2010.

	Year										
Stock Management Unit	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Western-central North Sea	1503,9	1213,2	994,5	1155,1	1038,7	956,5	1315,2	1271,2	967,0	1122,7	1115,4
Eastern-central North Sea	4,2					48,4	761,9	1274,6	971,7	916,0	799,9
Southern North Sea	3130,9	3723,2	3551,6	4087,4	3524,5	2521,2	2240,9	2348,2	2260,5	1934,3	2323,0
Eastern Channel	376,2	426,6	310,7	287,1	277,1	266,3	321,6	228,3	284,4	320,2	345,9
Western Channel	5219,8	5061,7	5135,5	6066,5	4187,6	3330,4	3921,6	4586,0	4609,5	4217,6	4381,3
Celtic Sea	741,1	1006,2	704,6	663,5	755,1	666,9	1284,8	1489,1	1621,1	1717,5	2219,4
Irish Sea	80,6	117,8	214,1	132,5	52,0	35,7	256,9	303,5	211,0	141,5	147,9
Outside	12,0	223,6	402,2	141,8	1,4			0,1		0,2	0,7
Total	11068,6	11772,5	11313,3	12533,8	9836,4	7825,4	10102,9	11501,0	10925,4	10370,1	11333,5

Table 5 D. Landings (tons), number of vessels, number of pots and catch per unit effort (CPUE) from different assessment units and fishing fleets from 2000 to 2010, for *Cancer pagurus* in France.

Year	Eastern Channel	Western Channel	Celtic Sea	Total-landings	Offshore Potters (number)	Fishing effort (pots) Offshore	Daily fishing effort (# pots)	Landing s offshore potters	AI-Eastern Channel, CPUE (kg/pot)	AI-North Western Channel, CPUE (kg/pot)	AI-South Western Channel, CPUE (kg/pot)	Ail Celtic Sea, CPUE (kg/pot)
2000	433	4503	246	5182	17	2091905	916	2693	1808	1327	1562	1600
2001	498	4811	203	5513	17	2057700	929	2810	1851	1386	1560	1500
2002	525	4924	514	5963	17	1952320	921	2565	1986	1312	1547	1685
2003	368	5686	273	6327	17	2075675	956	2905	1649	1567	1704	1633
2004	394	7078	341	7813	15	2213970	950	3137	1611	1504	1725	1695
2005	437	5504	317	6259	15	1788690	960	2560	1689	1353	1680	1603
2006	315	4633	475	5423	14	1650550	986	2266	1466	1414	1755	1893
2007	253	5553	372	6178	13	1652375	966	2665	1747	1753	1836	1719
2008	264	5795	357	6416	11	1393900	974	2770	1261	2091	2124	2028
2009	333	3794	225	4353	13	1100000	984	1600	1211	1550	1846	2051
2010	449	4616	422	5487	12	1700000	974	2600	0	1478	1699	1732

Table 5 E. Annual *Cancer pagurus* landings (tonnes) into Scotland by creel fishery assessment unit from 2001–2010. Data from Fisheries Management database.

Assessment unit	Year									
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Clyde	86.7	53.8	57.0	21.0	39.6	198.2	250.3	213.7	99.4	139.3
East Coast	855.3	529.1	426.5	369.5	405.9	830.4	884.2	866.9	778.6	1029.0
Hebrides	1831.4	1613.3	1452.9	1381.9	1730.0	2279.4	2340.0	1738.4	1822.3	1885.8
Mallaig	17.9	2.0	1.6	6.7	5.2	7.7	67.0	32.4	8.5	12.9
North Coast	614.9	497.1	793.4	318.2	488.1	435.8	513.8	348.7	568.3	681.9
Orkney	1539.2	1498.6	1362.2	1309.5	1582.2	1467.9	1555.4	1187.3	1155.6	1462.1
Papa	694.8	771.9	785.2	463.5	454.1	838.2	798.0	764.1	1002.0	878.2
Shetland	416.2	331.8	217.1	33.3	193.8	640.8	522.4	566.9	390.2	334.4
South East	148.1	96.8	23.0	129.0	166.0	273.8	281.8	325.5	308.0	345.7
South Minch	1112.7	1195.5	1116.3	961.2	1389.1	1316.2	2149.6	1141.0	1000.7	1651.3
Sule	788.2	952.4	865.6	1389.7	1357.9	1663.1	2026.1	1836.2	1981.8	1928.9
Ullapool	146.1	199.8	233.2	194.2	271.7	358.1	376.0	241.9	192.1	245.4
Outside Assess. Units	206.9	131.5	190.7	183.8	249.0	120.5	154.1	73.1	158.7	261.9
Total	8458.4	7873.7	7524.6	6761.3	8332.5	10430.3	11918.7	9336.1	9466.1	10856.7

Table 5 F. Landings (tons) of *Cancer pagurus* in Norway per area 1977–2011 (data until November 2011).

	Landings with unknown area	North Sea (area 41)	Skagerrak (area 9)	Southwest Norway (area 8)	Middle Norway (area 28)	South Trøndelag / Møre and Romsdal (area 7)	North Trøndelag / Helgeland (area 6)	Lofoten (area 0)	Vesterålen (area 5)	Troms (area 4)	Total
1977	1 078			198	282	577	216				2351
1978	106		1	205	369	1 434	449		2		2565
1979	349			186	341	1 405	439		2		2721
1980	193			216	330	1 231	200		8		2178
1981	53			181	367	1 308	262		1	4	2175
1982	33		6	181	470	1 150	223		12		2074
1983	134		19	175	253	1 013	186		5		1784
1984	191		188	59	261	1 093	275		2	2	2070
1985	218			479	319	913	361		12		2302
1986	76			390	296	936	356		46	1	2101
1987	14			276	154	640	199		25		1307
1988	4		18	290	266	583	129		58		1349
1989	8			290	259	681	173		38		1449
1990	1			175	306	718	173		1		1374
1991			1	210	307	820	125				1462
1992			2	236	203	842	33				1316
1993			2	330	249	1 046	13				1641
1994			1	308	246	1 029	196				1781
1995			1	368	214	1 085	139				1806

1996			1	414	242	1 110	122				1889
1997			2	490	305	1 166	243				2205
1998			1	518	277	1 711	476				2984
1999			1	540	257	1 440	598				2836
2000			1	465	206	1 499	718	1			2890
2001			2	432	242	2 116	684	2			3478
2002			4	496	366	2 676	800	2	1		4344
2003			4	527	532	2 247	1 589	28	17		4944
2004			5	677	503	1 994	2 013	54	2		5248
2005			7	625	486	1 858	2 392	298	5		5671
2006		2	9	640	334	2 116	2 768	336	1		6205
2007			11	735	466	2 619	4 172	510	2		8514
2008		1	6	658	172	2 056	1 998	402	1	1	5295
2009			6	692	226	2 140	1 605	301	1		4970
2010		0	38	682	300	2 324	2 381	49			5772
2011		0	43	709	276	2 087	1 873	35		0	5 023

Table 5 G. Landings (tonnes) from the Shetland *Cancer pagurus* inshore fishery (within 6 nm).

Year	Landings (Tonnes)
2000	293.02
2001	274.08
2002	192.10
2003	202.04
2004	245.26
2005	333.68
2006	393.02
2007	330.61
2008	283.32
2009	232.10
2010	287.70

Landings

Landings of *Cancer pagurus* have remained stable in most areas in the ten most recent years (Tables 5 C – 5 G).

5.1 Stock summary for *Cancer pagurus* fisheries in England and Wales

Provided by Cefas

Assessment units

Stock boundaries for edible crab remain poorly understood despite genetic studies that suggested greater heterogeneity than previously thought and the possibility of locally differentiated stocks. Both sexes are known to move quite widely, the females in particular have been shown to travel large distances, generally in a direction counter to residual tidal flows (the likely direction of larval drift.)

Studies on larval distribution and hydrographic conditions in the North Sea suggests recruitment to the two areas north and south of Flamborough head could be distinct. Similar studies in the Channel have raised the possibility of separation of spawning populations in the east Channel from the west Channel/Western Approaches, but the mechanisms of and factors controlling recruitment are not clearly understood.

Following discussions at the Crab 2010 WG some modifications will be made to a few of the boundaries to facilitate international collaboration (see Figure 5.1). These changes will have limited or no effect on the National assessments presented below (Table 5.1.1).

Table 5.1.1 *Cancer pagurus* fishery assessment units in England and Wales.

No	Name	Sea area boundaries
1	Central North Sea	ICES division IVb north of 54° N
2	Southern North Sea	Between latitudes 51° 30′ N and 54°N
3	Eastern Channel	ICES divisions VIId east of 1° W and IVc south of 51° 30′ N
4	Western Channel and Western Approaches	ICES divisions VIIe, VIIh, VIIIa and VIId west of 1° W
5	Celtic Sea	ICES divisions VIIf and VIIg
6	Irish Sea	ICES division VIIa

Landings and fishing effort

Fishing activity data in England and Wales is recorded by the Marine Management Organisation (MMO) onto an official national database (FAD). For the potting fleets prosecuting *Cancer pagurus*, the primary sources of data were monthly shellfish activity returns (MSARs as part of the Restrictive Shellfish License Scheme, RSLS) for the <10m fleet and EU logbooks for >=10m vessels. Before the introduction of RSLS in January 2006 and the mandatory completion of EU logbooks in January 2010 the activity data for the two relevant components of the potting fleets were not comprehensive. Recently the main source of data has changed to sales notes which are provided by fishers and merchants in electronic or paper format. Over time inconsistent reporting procedures have provided data varying in levels of quality and completeness. Prior to 1983 activity data for the potting fleet is not readily available and early fishing effort data in particular is of poor quality. The following figures are based on retrievals from FAD for English and Welsh vessels using potting gears (Table 5 C). The index of fishing effort used is days fished which although not as informative as numbers of pots hauled is considered more reliable.

Landings per Unit Effort

A logbook scheme run by the Centre for the Environment, Fisheries and Aquaculture Science (Cefas) and designed to provide representative and detailed activity data for a selected number of potting vessels around England and Wales operated from 1983 to 2007. These data although limited by participant numbers are considered higher quality than series generated solely from the official national data. Following the cessation of the scheme, data from FAD have been used to continue the trends for the original vessels. Trends from 2008 may or may not be directly comparable with earlier trends due to alternative interpretation of the data by the two agencies concerned. There were no contributors to the original scheme for the Eastern Channel and Celtic Sea assessment units so an aggregated LPUE was computed from the official database. These trends may not be as informative as individual vessel time-series. Where logbook data is available LPUE is presented as kg/100 pots hauled, otherwise kg/days fished.

Discards

Discard sampling of the potting fleet is not carried out in a routine manner and consistent data suitable for annual assessment is not available. Data collected as part of EU data regulations and *ad hoc,* often opportunistic sampling, does provide some information (not presented).

Length/width frequency data

Historically biological length samples were collected by the MMO, in some years augmented by Cefas sampling. Since 1983 these data are readily available in electronic format.

Length distributions used for LCA and per recruit analyses were generated using LD's archived on the official Biological Sampling System database and raised using R script. R code was also used to produce the length distribution time-series graphics.

For most areas and years adequate sampling intensity has enabled rising to annual LD's except in the Irish Sea where sampling levels have been consistently very low.

Assessment methodology

Length based VPA

Length cohort analysis (LCA; Jones, 1981; 1984) produces estimates of population numbers and fishing mortality at length, given growth parameters, assumptions regarding natural mortality and a catch length frequency distribution from a population assumed to be at equilibrium. The duration of time spent in each length class is calculated using the growth parameters. Estimates of the population number entering each length class can be made by Pope's cohort analysis approximation but in this case by numerically solving the catch equation (Sparre *et al.*, 1989). The process continues recursively estimating fishing mortality and numbers backwards along the 'pseudo-cohort'.

Yield, spawner and egg per recruit

The yield per recruit (YPR) model (Beverton & Holt, 1957) works by assuming an arbitrary number of recruits and projecting them forward based on fishing and natural mortality to estimate numbers in each size class during the lifetime of the cohort. Numbers are subsequently divided by the number of recruits to obtain the 'per recruit' estimates. Weight, proportion mature and fecundity by size are applied to estimate yield, SSB or number of eggs by size class, which are summed over all classes. Per recruit models have been extensively used for crustacean fisheries.

Uncertainties

The quality of landings data and, in particular, effort data from the official national database are variable through time and may at times reflect changes in the efficacy of recording rather than the crab fishery itself. Compulsory completion of EU logbooks for over 10m vessels in January 2000 and the introduction of the SRLS in January 2006 give obvious peaks in the activity data for some areas suggesting under reporting in previous time periods. Changes in the database structure, in particular input forms have also produced effects.

Length based VPA and per recruit modelling make steady state assumptions that the population and fishery that are in equilibrium. Stock identities for edible crabs are not well understood and crabs are known to be able to move large distances. It is likely that the steady state assumptions are violated due to the biological and behavioural factors mentioned and developments in the crab fisheries, where effort is thought to have increased in recent years due to the deployment of more fishing gear. These analyses are also sensitive to the growth parameters used, choice of plus group and assumptions regarding natural mortality, again areas of knowledge where understanding and, more particularly quantification, are lacking for edible crabs and macro crustaceans in general.

Poor levels of biological sampling may give rise to biased or unrepresentative length distributions, and influence the estimation of fishing mortality and subsequent per recruit analyses. This problem is particularly acute if low levels of sampling are combined with high raising factors and the practice of grading of crabs by sex in some regions exacerbates these factors particularly for the large market grade (CRC). In some fisheries management areas there is some evidence to suggest that expansion of the fisheries farther offshore has yielded biological samples containing crabs of higher mean size, an artefact which may suggest improving stock status contrary to anecdotal information regarding the traditional fisheries.

Table 5.1.2. Universal assessment parameters for *Cancer pagurus* assessment in England and Wales.

Parameter	Female	Male	Source
von Bertalanffy k	0.196	0.191	Addison and Bennett 1992
von Bertalanffy L_∞	240	240	Addison and Bennett 1992
Size at maturity a	-10.4438	-10.4166	Cefas unpublished
Size at maturity b	0.0936	0.1163	Cefas unpublished
Weight length a	-8.57408	-10.2119	Cefas unpublished
Weight length b	2.947	3.301	Cefas unpublished
Fecundity at size a	0.0187	NA	Cefas unpublished
Fecundity at size b	0.0268	NA	Cefas unpublished
Natural mortality (all sizes)	0.1 and 0.2	0.1 and 0.2	Plausible alternatives

Data by assessment unit

Central North Sea

Landings and fishing effort

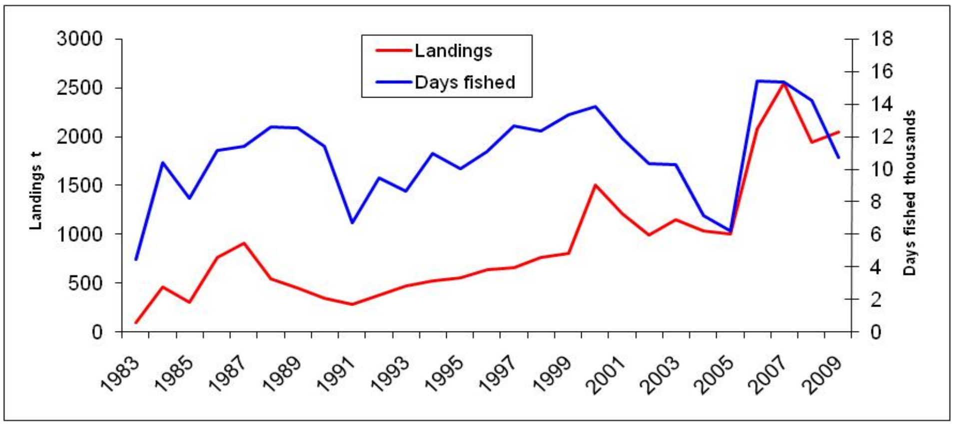

Figure 5.1.1 Time-series of *Cancer pagurus* landings (tonnes: red) and effort (days fished: blue) from the Central North Sea.

Landings per Unit Effort

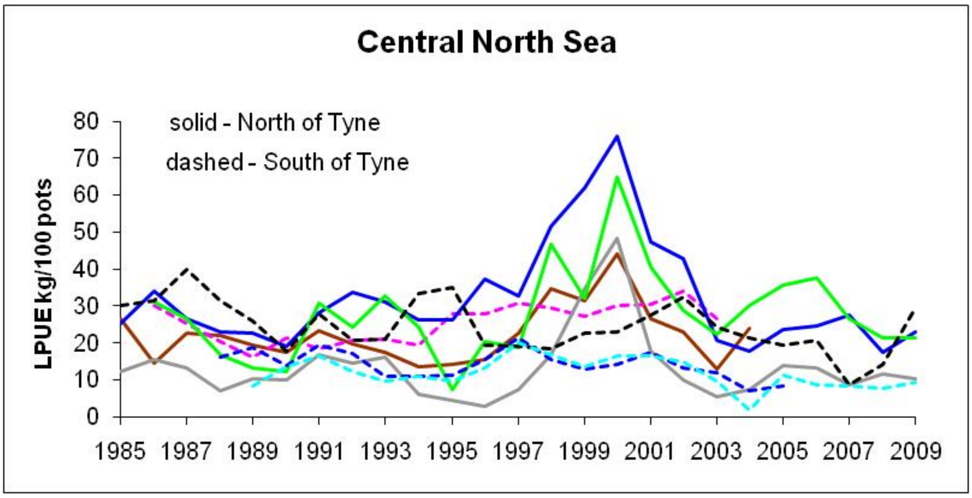

Figure 5.1.2. Time-series of *Cancer pagurus* landings per unit effort from the Central North Sea. Dashed lines are vessels fishing south of the River Tyne and solid lines those to the North.

Length/width frequency data

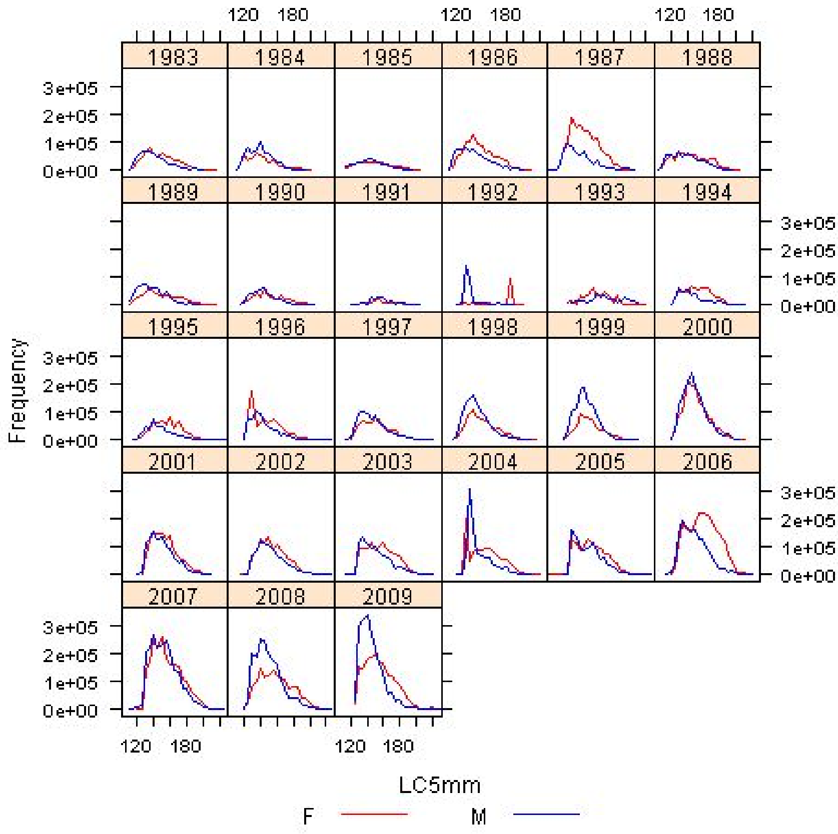

Figure 5.1.3. Time-series of landings raised length distributions for female and male *Cancer pagurus* from the Central North Sea.

Table 5.1.3. Specific assessment parameters for Central North Sea.

Parameter	Female	Male	Source
Plus group	210mm	210mm	Data derived
Terminal exploitation rate	0.88 and 0.8	0.9 and 0.77	Data derived

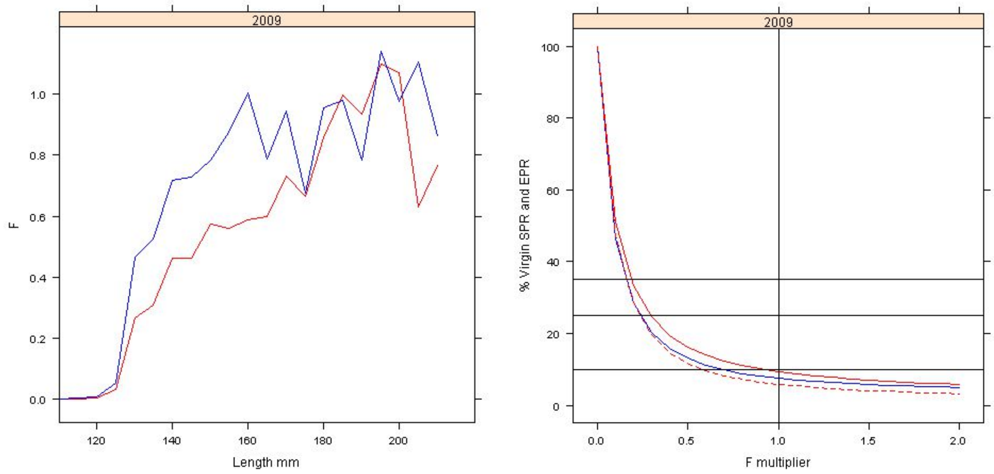

Figure 5.1.4. Fishing mortality for Central North Sea by 5 mm size class, estimated by length based VPA (M=0.1).

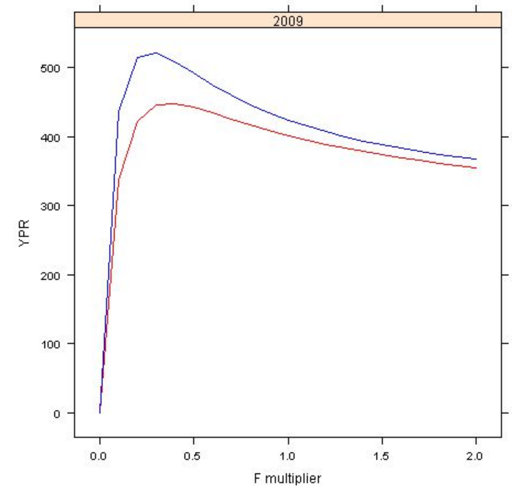

Figure 5.1.5. Central North Sea yield, spawner and egg per recruit curves assuming M=0.1 with lines indicating reference levels (F_{sq}, 35%, 25% and 10% of virgin SPR and EPR).

Stock status

Table 5.1.4. Central North Sea summary of stock and fishery performance against reference points.

					Implications of moving to reference point	
Natural Mortality	**Sex**	**Reference point**	**Limit or target**	**Current status**	**Fishing mortality % cut**	**Yield Per Recruit % gain**
0.1	F	F_{max}	T/L	Fsq > Fmax	64	12
		$F_{0.1}$	T		84	0
		35%VirgSPR	T	9	81	4
		25%VirgEPR	T	6	77	8
		10%VirgEPR	L	6	42	8
	M	F_{max}	T/L	Fsq > Fmax	74	23
		$F_{0.1}$	T		87	12
		35%VirgSPR	T	10	85	17
0.2	F	F_{max}	T/L	Fsq > Fmax	10	4
		$F_{0.1}$	T		67	-8
		35%VirgSPR	T	33	54	-1
		25%VirgEPR	T	25	49	0
		10%VirgEPR	L	25	-69	1
	M	F_{max}	T/L	Fsq > Fmax	40	0
		$F_{0.1}$	T		74	-10
		35%VirgSPR	T	35	65	-3

LPUE trends for a subset of individual vessels indicate that in the north of this area catch rates increased in the late 1990s, but they have since returned to average levels. In the south of this region catch rates generally declined slightly from 2002 or 2003.

Length distributions suggest that landings of large female crabs were high in 2006, but have subsequently declined, while landings of male crabs in this area have increased during the last 2 years.

Yield per recruit analyses suggest fishing mortality for both sexes is above levels that would maximise long term yields under both alternative assumptions used for natural mortality.

Fishing mortality is also above levels required to meet potential egg and spawner per recruit based targets and limits assuming M = 0.1, but the potential EPR limit reference point is achieved if an assumption of M = 0.2 is used.

Moving to these potential limit and/or target reference points would require very substantial reductions in F under an assumption of M = 0.1, but this would also imply some YPR and SPR gains. If an assumption of M = 0.2 is used reductions required in F to achieve these potential reference levels are still substantial (apart from achieving the 10% virgin EPR limit) and the changes in YPR are generally small and negative.

Southern North Sea

Landings and fishing effort

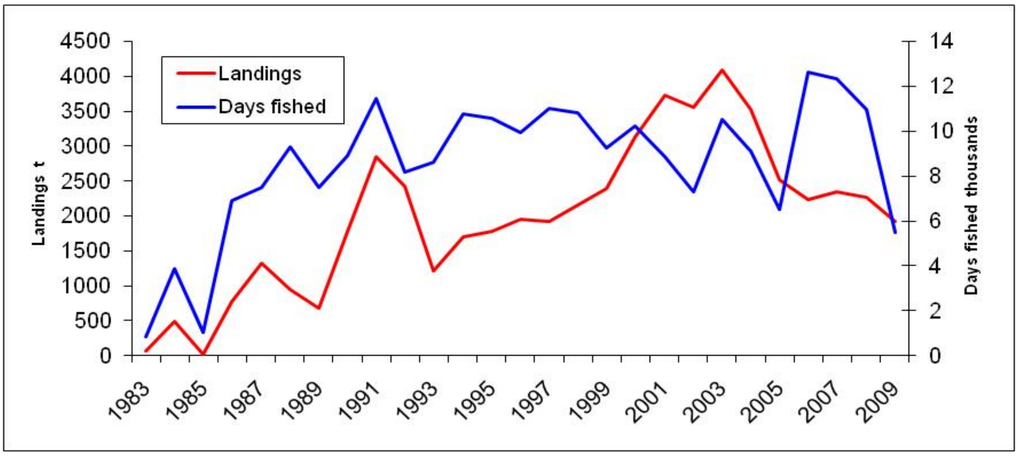

Figure 5.1.6. Time-series of *Cancer pagurus* landings (tonnes: red) and effort (days fished: blue) from the Southern North Sea.

Landings per Unit Effort

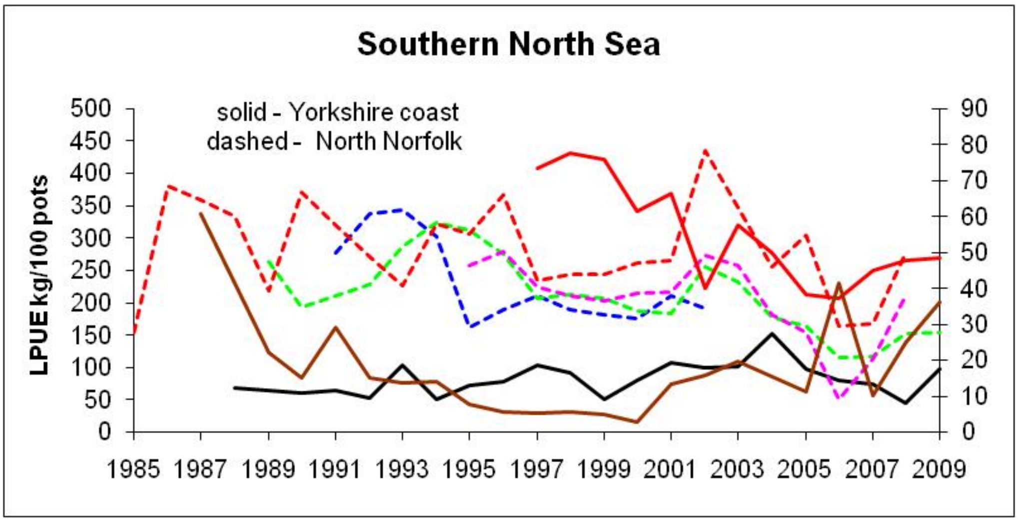

Figure 5.1.7. Time-series of *Cancer pagurus* landings per unit effort from the Southern North Sea. Dashed lines are vessels working off North Norfolk and solid lines vessels off the Yorkshire coast.

Length/width frequency data

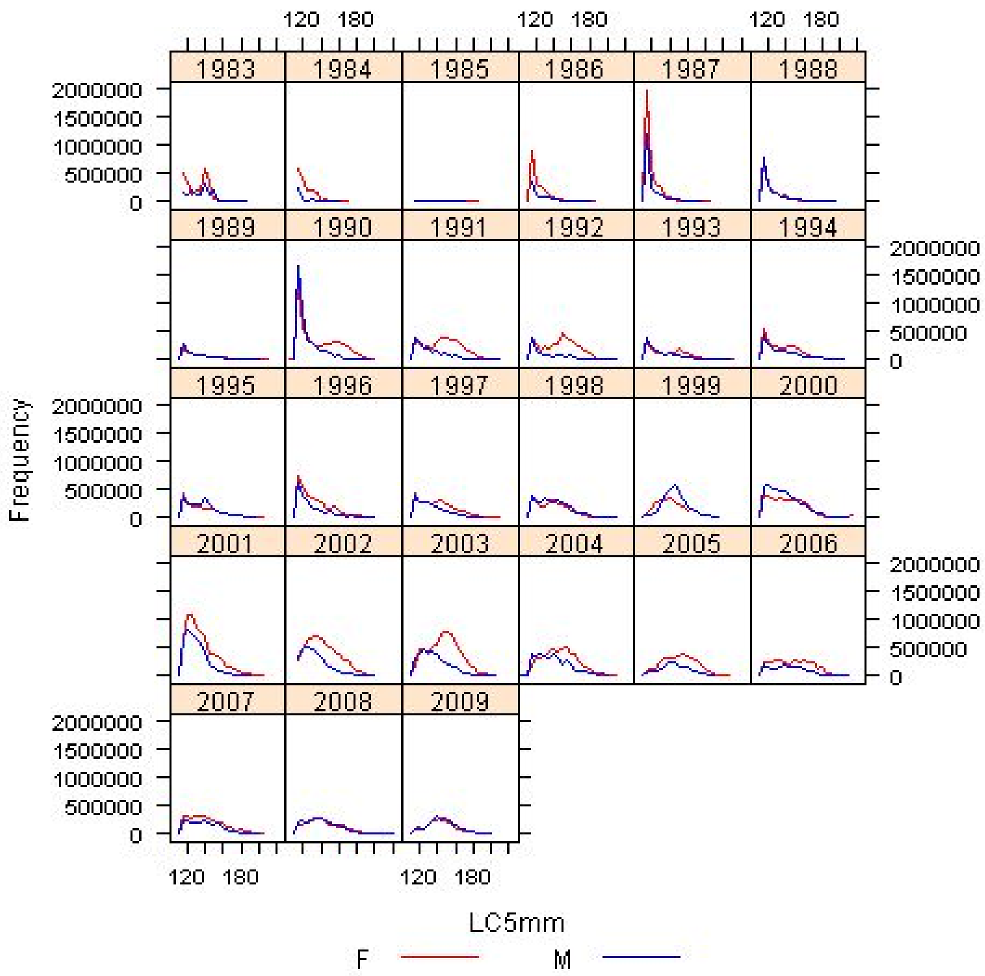

Figure 5.1.8. Time-series of landings raised length distributions for female and male *Cancer pagurus* from the Southern North Sea.

Assessment

Table 5.1.5. Specific assessment parameters for Southern North Sea.

Parameter	Female	Male	Source
Plus group	200mm	200mm	Data derived
Terminal exploitation rate	0.9 and 0.83	0.91 and 0.8	Data derived

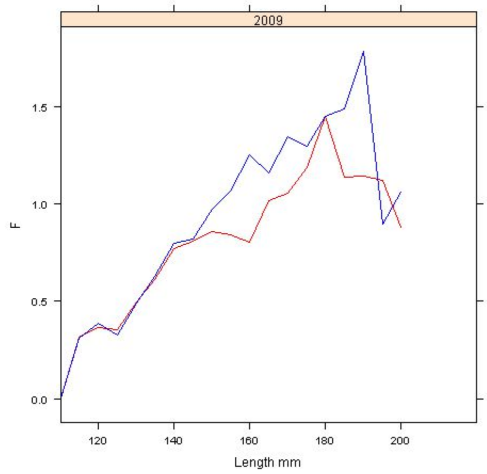

Figure 5.1.9. Fishing mortality for Southern North Sea by 5 mm size class, estimated by length based VPA (M= 0.1).

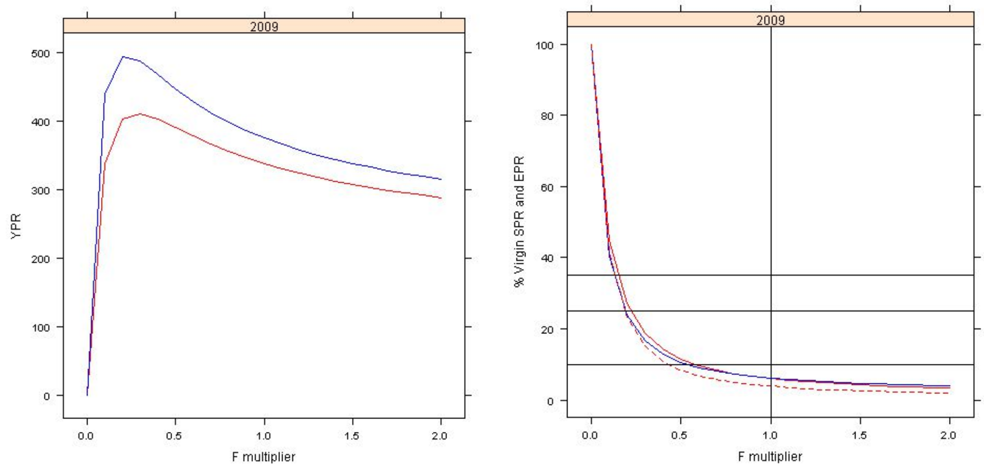

Figure 5.1.10. Southern North Sea yield, spawner and egg per recruit curves assuming M= 0.1 with lines indicating reference levels (F_{sq}, 35%, 25% and 10% of virgin SPR and EPR).

Stock status

Table 5.1.6. Southern North Sea summary of stock and fishery performance against reference points.

					Implications of moving to reference point	
Natural Mortality	**Sex**	**Reference point**	**Limit or target**	**Current status**	**Fishing mortality % cut**	**Yield Per Recruit % gain**
0.1	F	F_{max}	T/L	Fsq > Fmax	72	22
		$F_{0.1}$	T		86	11
		35%VirgSPR	T	6	86	12
		25%VirgEPR	T	4	81	18
		10%VirgEPR	L	4	57	18
	M	F_{max}	T/L	Fsq > Fmax	78	32
		$F_{0.1}$	T		89	20
		35%VirgSPR	T	6	88	24
0.2	F	F_{max}	T/L	Fsq > Fmax	43	0
		$F_{0.1}$	T		75	-9
		35%VirgSPR	T	24	70	-6
		25%VirgEPR	T	19	64	-3
		10%VirgEPR	L	19	3	-3
	M	F_{max}	T/L	Fsq > Fmax	57	0
		$F_{0.1}$	T		80	-9
		35%VirgSPR	T	23	73	-3

LPUE trends for a subset of individual vessels suggest that in the North Norfolk fishery catch rates declined in the mid 1990s, followed by a peak in 2002/2003 and another decline. LPUE for two of the vessels in 2008 shows a partial recovery to more typical values. In the North of the area one offshore vessel showed a general and steep decline in catch rates since 1998, but with a slight recovery in recent years. Two inshore vessels show variable LPUE, with those for the last few years being typical or above average for the series.

Length distributions indicate that landings of both sexes of crabs have declined in recent years and possibly more so for females.

Yield per recruit analyses suggests fishing mortality for both sexes is above levels that would maximise long term yields under both assumptions used for natural mortality.

Fishing mortality is also well above levels required to meet potential egg and spawner per recruit based targets assuming both M=0.1 and M=0.2, although the EPR limit would be achieved with only a small reduction in effort if M=0.2 is assumed.

Moving to these potential limit and/or target reference points would require very substantial reductions in F under an assumption of M=0.1, but this would also imply significant YPR and SPR gains. Using an assumption of M = 0.2 the cuts in F required to achieve these reference levels are still substantial, while the changes in YPR are generally negative.

Eastern Channel

Landings and fishing effort

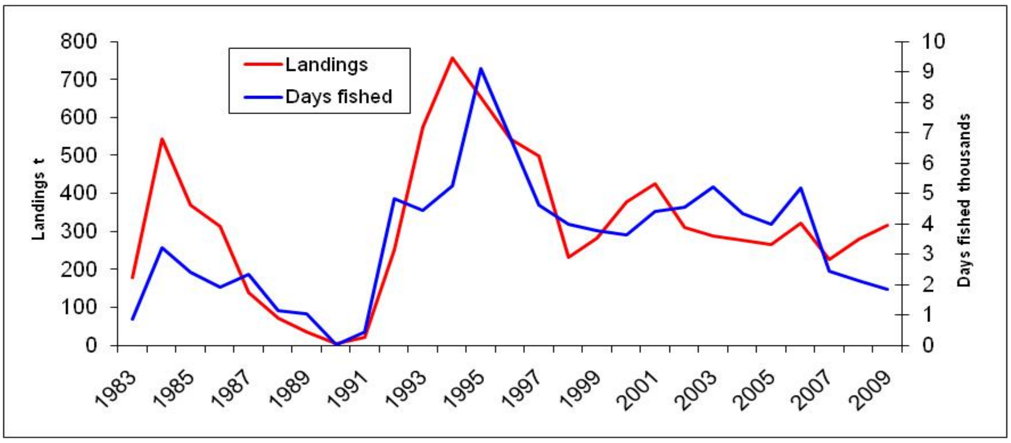

Figure 5.1.11. Time-series of *Cancer pagurus* landings (tonnes: red) and effort (days fished: blue) from the Eastern Channel.

Landings per Unit Effort

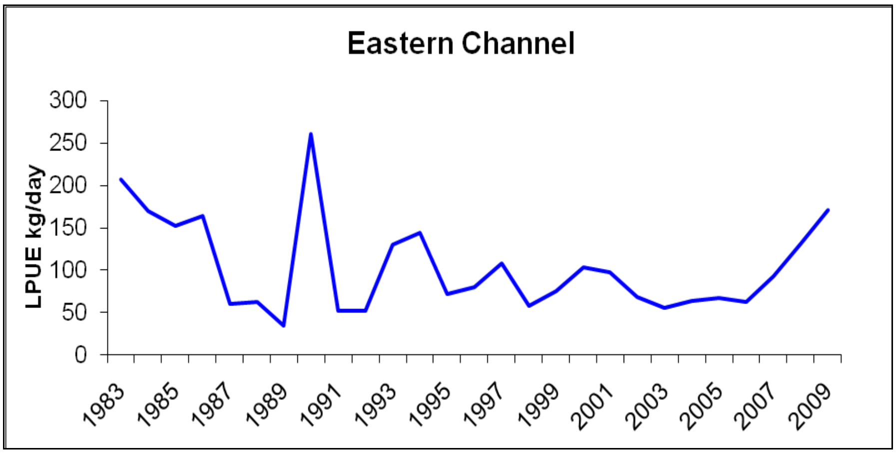

Figure 5.1.12. Time-series of *Cancer pagurus* landings per unit effort (FAD) from the Eastern Channel.

Length/width frequency data

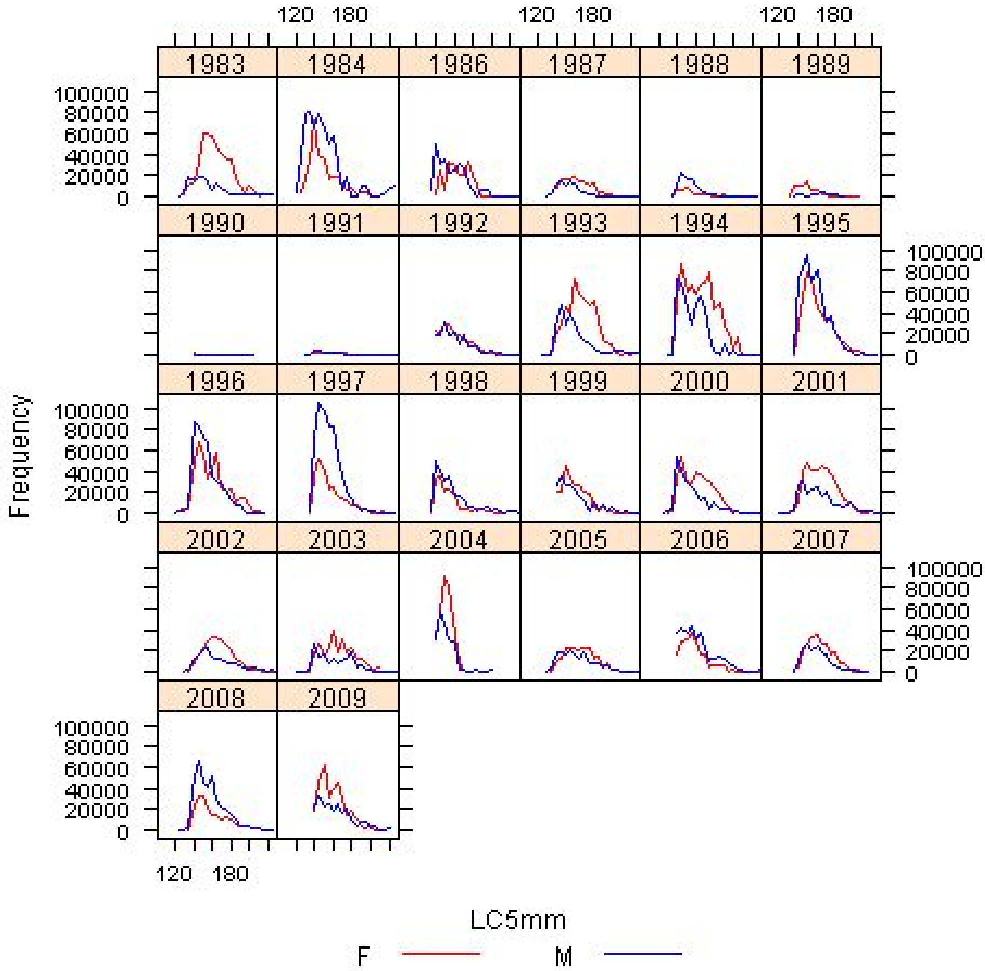

Figure 5.1.13. Time-series of landings raised length distributions for female and male *Cancer pagurus* from the Eastern Channel. Note 1985 is absents due to lack of sampling in this year.

Assessment

Table 5.1.7. Specific assessment parameters for Eastern Channel.

Parameter	Female	Male	Source
Plus group	200mm	200mm	Data derived
Terminal exploitation rate	0.85 and 0.72	0.87 and 0.75	Data derived

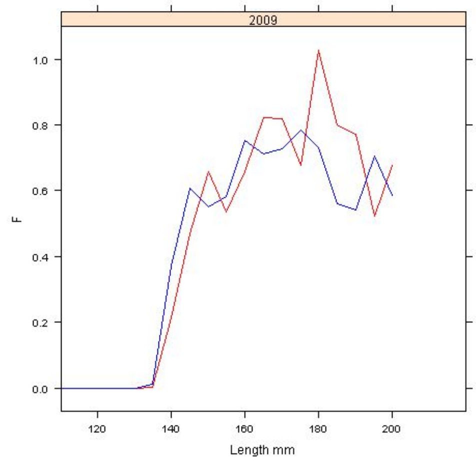

Figure 5.1.14. Fishing mortality for Eastern Channel by 5 mm size class, estimated by length based VPA (M=0.1).

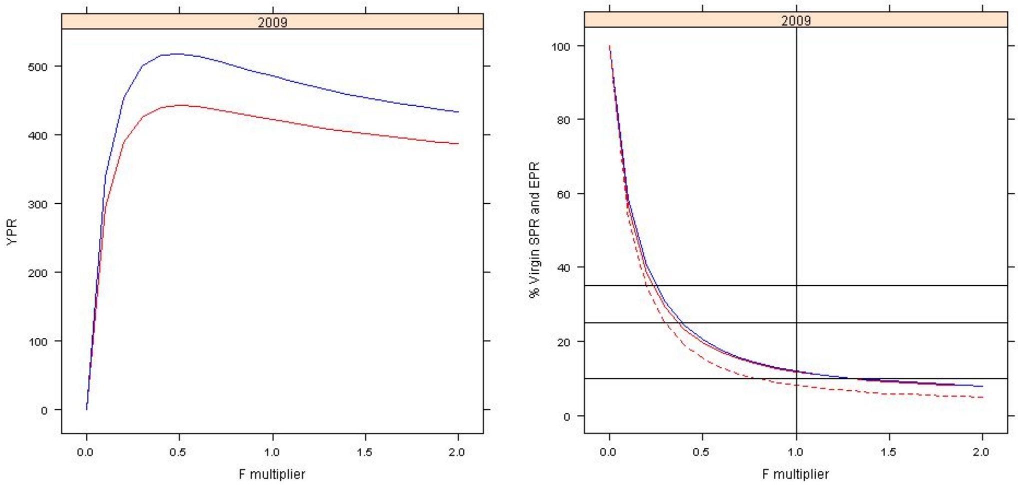

Figure 5.1.15. Eastern English Channel yield, spawner and egg per recruit curves assuming M=0.1 with lines indicating reference levels (F_{sq}, 35%, 25% and 10% of virgin SPR and EPR).

Stock status

Table 5.1.8. Eastern Channel summary of stock and fishery performance against reference points.

					Implications of moving to reference point	
Natural Mortality	Sex	Reference point	Limit or target	Current status	Fishing mortality % cut	Yield Per Recruit % gain
0.1	F	F_{max}	T/L	Fsq > Fmax	50	5
		$F_{0.1}$	T		79	-7
		35%VirgSPR	T	12	77	-4
		25%VirgEPR	T	8	70	1
		10%VirgEPR	L	8	21	3
	M	F_{max}	T/L	Fsq > Fmax	52	7
		$F_{0.1}$	T		78	-4
		35%VirgSPR	T	15	75	-1
0.2	F	F_{max}	T/L	Fsq < Fmax	-24	9
		$F_{0.1}$	T		58	-4
		35%VirgSPR	T	38	43	3
		25%VirgEPR	T	31	32	5
		10%VirgEPR	L	31	-199	6
	M	F_{max}	T/L	Fsq < Fmax	-12	9
		$F_{0.1}$	T		56	-3
		35%VirgSPR	T	50	38	4

LPUE trends as indicated from an aggregated index from the official database decreased from 2000 to 2006, but have been increasing slightly in recent years.

Length distributions suggest that landings of males were higher in 2008 than for several years. There has been a shift in the sex ratio observed in catches in this area, but it is not clear whether this is real or reflects relatively low sampling levels.

Yield per recruit analyses suggest fishing mortality for both sexes is well above levels that would maximise long term yields if a natural mortality of 0.1 were assumed. For an assumed natural mortality of M=0.2 fishing mortality is below F_{max}.

Fishing mortality is also well above levels required to meet potential egg and spawner per recruit based targets for both scenarios of natural mortality, but the egg per recruit limit reference point is achieved when M is assumed to be 0.2. Moving to the potential target reference points would require substantial reductions in F for both natural mortality assumptions, while the changes in YPR are generally small.

Western Channel

Landings and fishing effort

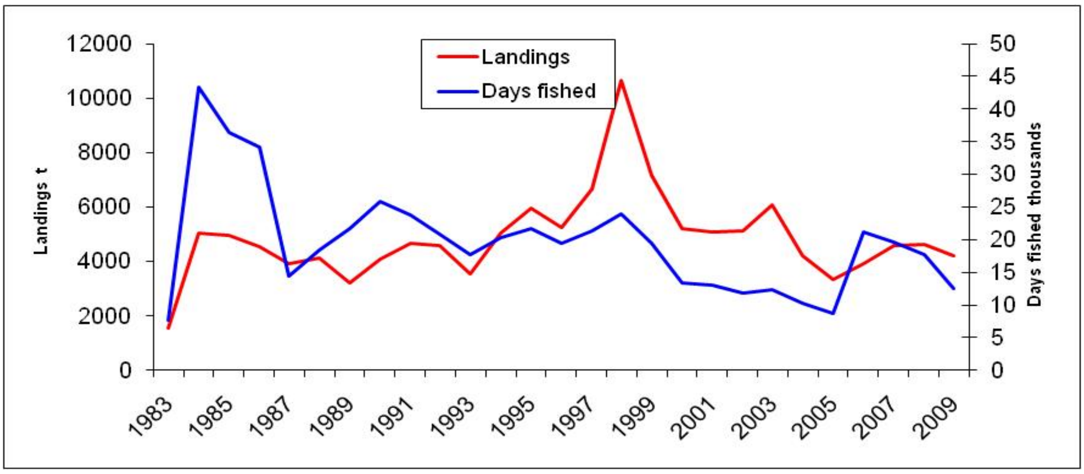

Figure 5.1.16. Time-series of *Cancer pagurus* landings (tonnes: red) and effort (days fished: blue) from the Western Channel and Western Approaches.

Landings per Unit Effort

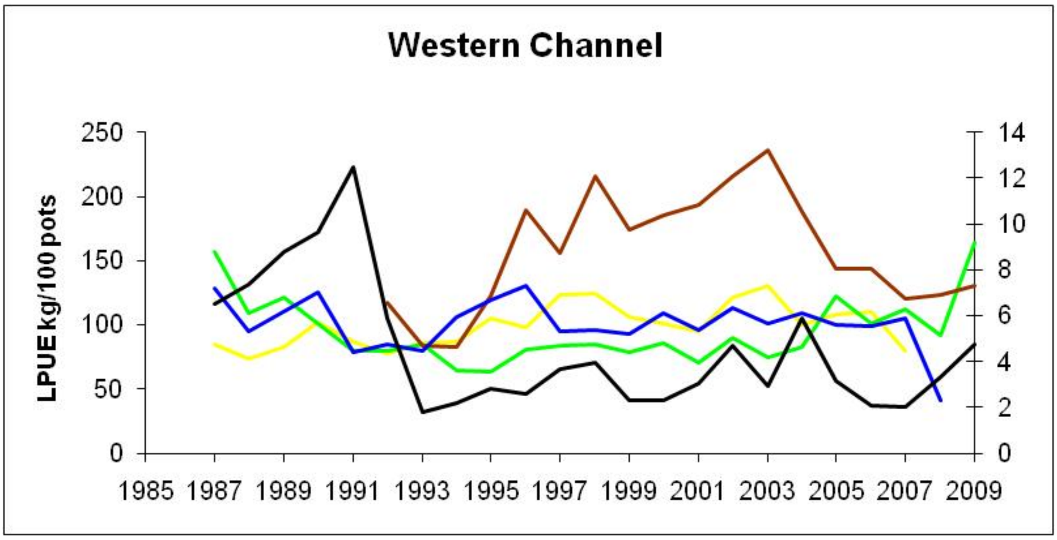

Figure 5.1.17. Time-series of *Cancer pagurus* landings per unit effort from the Western Channel and Western Approaches.

Length/width frequency data

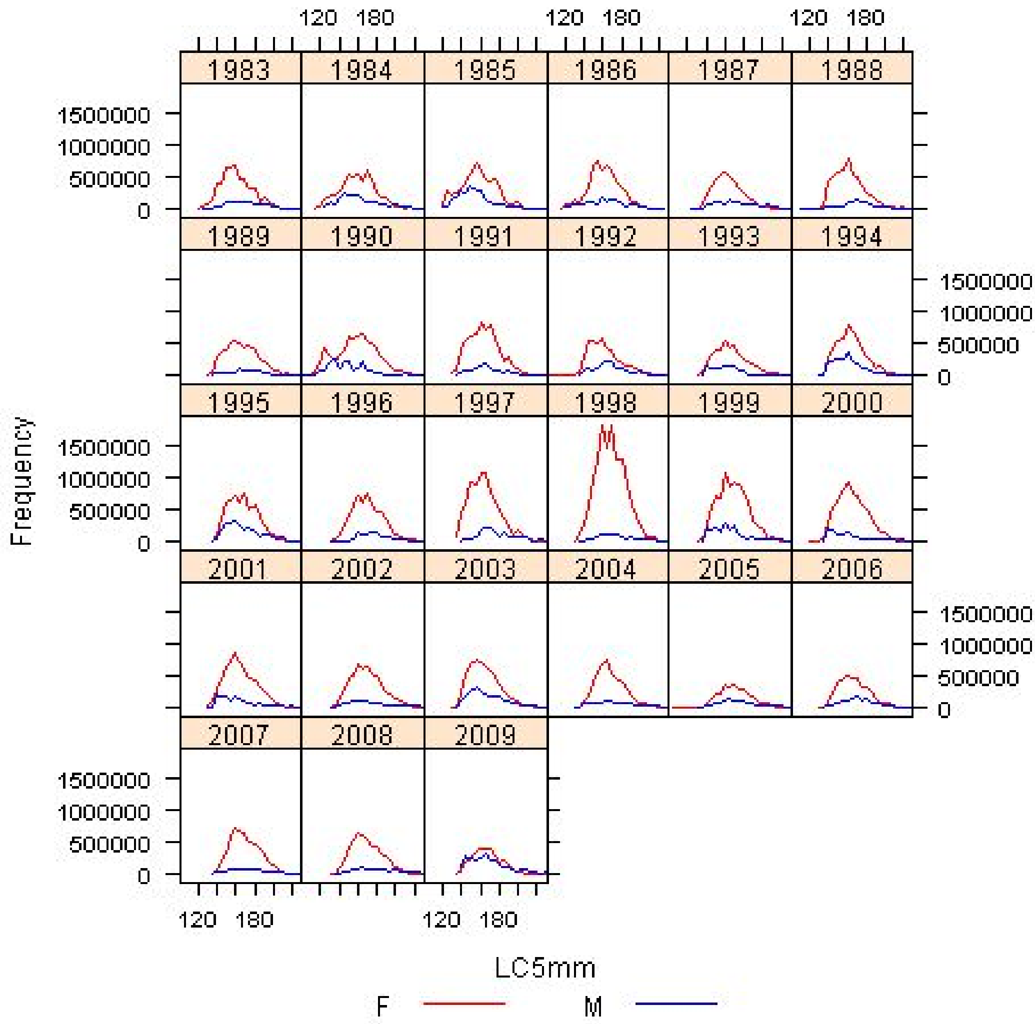

Figure 5.1.18. Time-series of landings raised length distributions for female and male *Cancer pagurus* from the Western Channel and Western Approaches.

Assessment

Table 5.1.9. Specific assessment parameters for Western Channel.

Parameter	Female	Male	Source
Plus group	210mm	210mm	Data derived
Terminal exploitation rate	0.72 and 0.51	0.86 and 0.73	Data derived

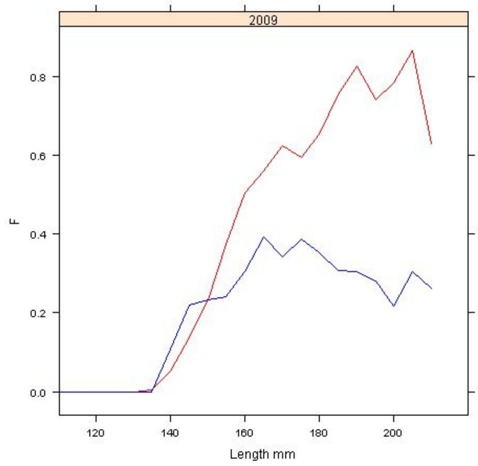

Figure 5.1.19. Fishing mortality for the Western Channel and Western Approaches by 5 mm size class, estimated by length based VPA (M=0.1).

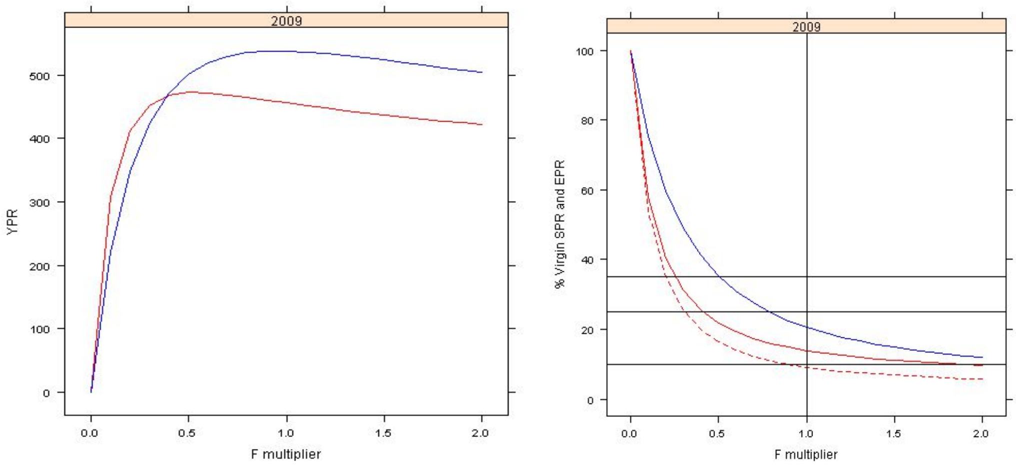

Figure 5.1.20. Western Channel yield, spawner and egg per recruit curves assuming M=0.1 with lines indicating reference levels (F_{sq}, 35%, 25% and 10% of virgin SPR and EPR).

Stock status

Table 5.1.10. Western Channel summary of stock and fishery performance against reference points.

					Implications of moving to reference point	
Natural Mortality	**Sex**	**Reference point**	**Limit or target**	**Current status**	**Fishing mortality % cut**	**Yield Per Recruit % gain**
0.1	**F**	F_{max}	T/L	Fsq > Fmax	47	4
		$F_{0.1}$	T		79	-8
		35%VirgSPR	T	14	75	-4
		25%VirgEPR	T	9	69	0
		10%VirgEPR	L	9	11	1
	M	F_{max}	T/L	Fsq > Fmax	5	0
		$F_{0.1}$	T		55	-9
		35%VirgSPR	T	26	49	-6
0.2	**F**	F_{max}	T/L	Fsq < Fmax	-64	12
		$F_{0.1}$	T		56	-3
		35%VirgSPR	T	42	27	7
		25%VirgEPR	T	34	20	8
		10%VirgEPR	L	34	-387	9
	M	F_{max}	T/L	Fsq < Fmax	-190	54
		$F_{0.1}$	T		-7	36
		35%VirgSPR	T	78	-57	48

LPUE trends for a subset of logbook participants are consistent in the main, but one large offshore vessel fishing mid Channel has shown a substantial decrease in LPUE since 2003, whilst two vessels had higher catch rates before and during the early 1990s.

When assuming M=0.1,yield per recruit analyses suggest fishing mortality for females is above the level that would maximise long term yield and fishing mortality for males is close to F_{max}. If a natural mortality of 0.2 is assumed, fishing mortality for both sexes is below levels which would maximise yields.

Fishing mortality for both sexes is well above levels required to meet potential egg and spawner per recruit based targets and limits, assuming M=0.1. Assuming a natural mortality of 0.2 to achieve the female 35% virgin SPR and 25% virgin EPR targets would require a reduction in fishing effort. However, the 10% virgin EPR limit reference and male 35% SPR target reference are achieved at current F.

Moving to the potential or target reference points for females would generally require substantial (M=0.1) or moderate (M=0.2) reductions in F, associated with small changes in YPR.

Celtic Sea

Landings and fishing effort

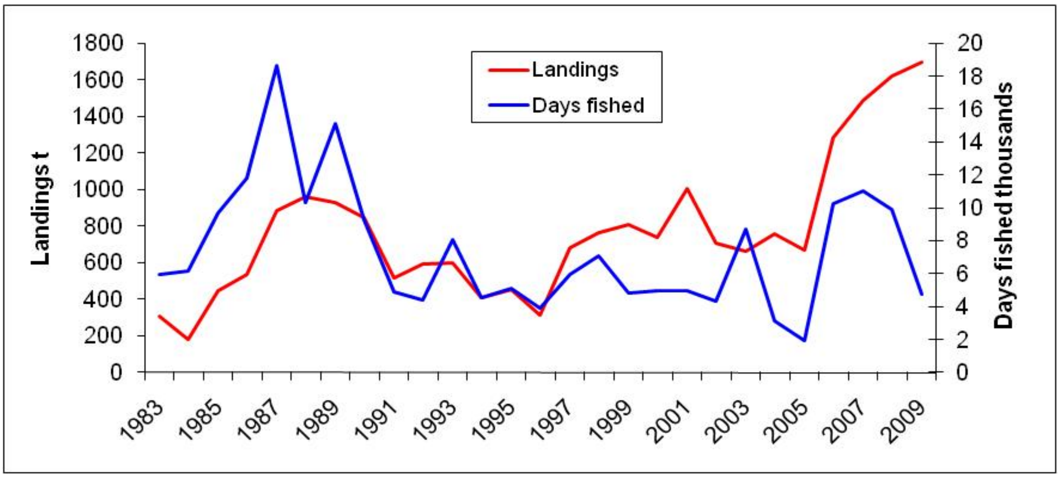

Figure 5.1.21. Time-series of crab landings (tonnes: red) and effort (days fished: blue) from the Celtic Sea.

Landings per Unit Effort

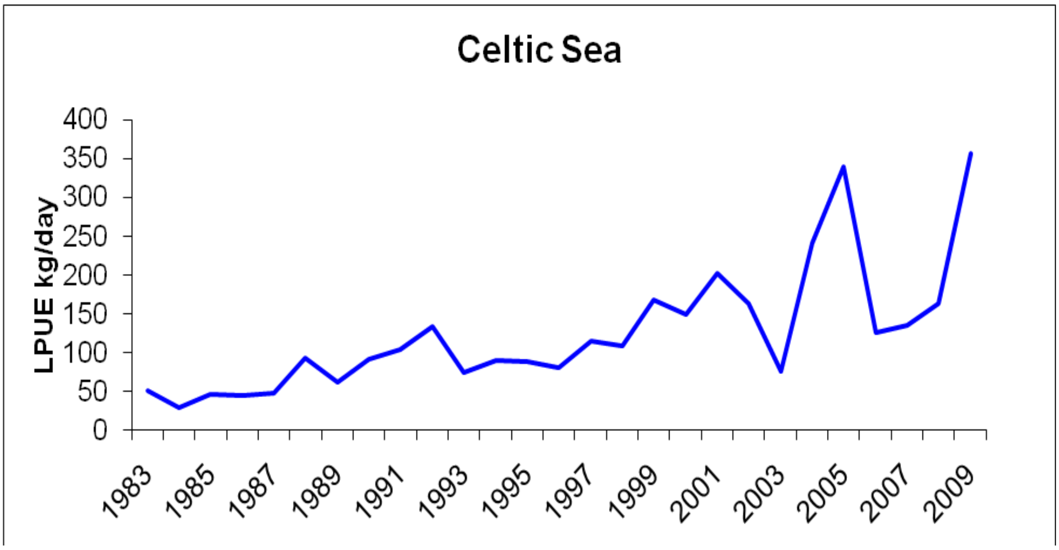

Figure 5.1.22. Time-series of *Cancer pagurus* landings per unit effort (FAD) from the Celtic Sea.

Length/width frequency data

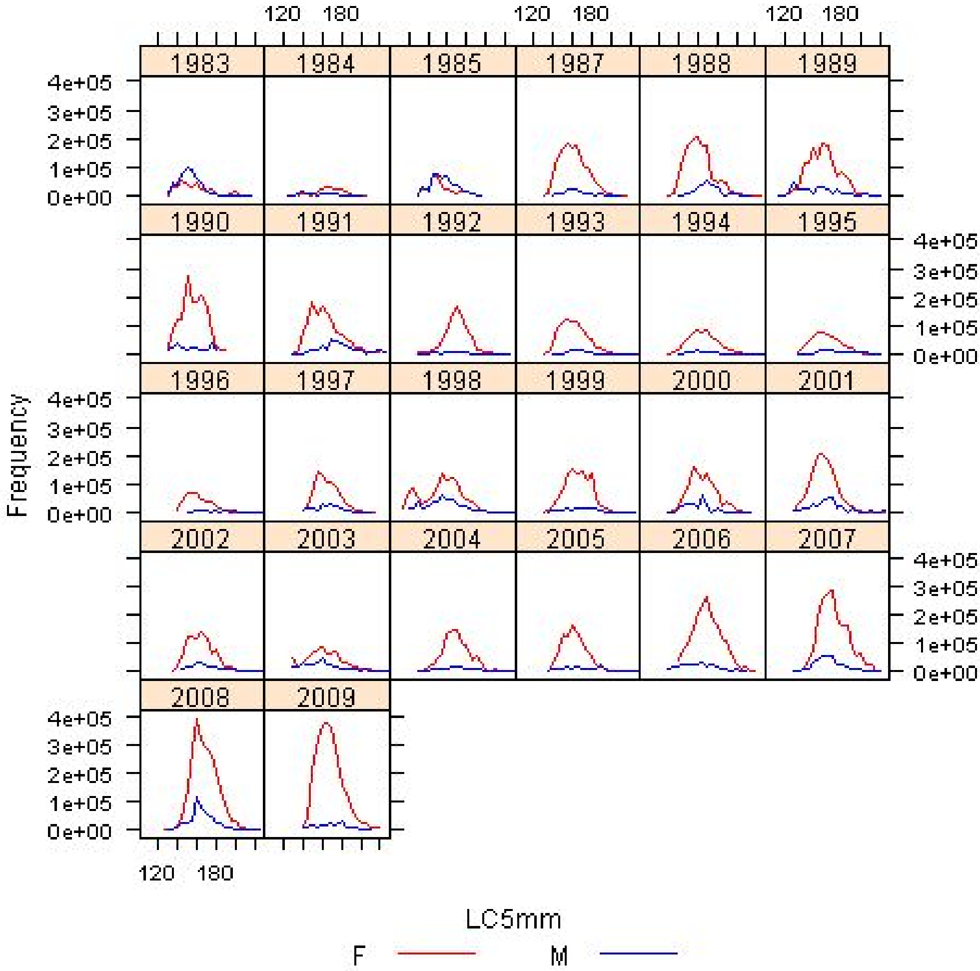

Figure 5.1.23. Time-series of landings raised length distributions for female and male *Cancer pagurus* from the Celtic Sea (Note missing year, 1986, when no samples were available).

Assessment

Table 5.1.11. Specific assessment parameters for Celtic Sea.

Parameter	Female	Male	Source
Plus group	210mm	210mm	Data derived
Terminal exploitation rate	0.9 and 0.81	0.88 and 0.77	Data derived

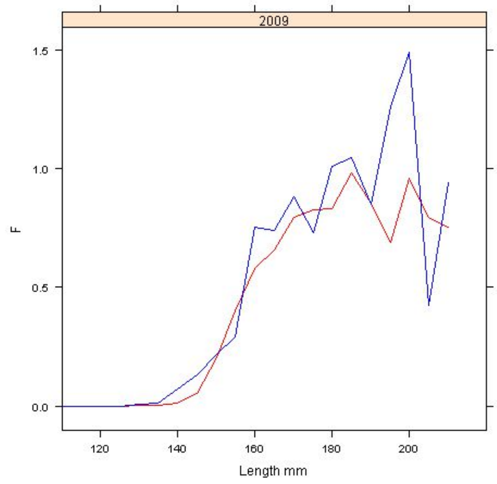

Figure 5.1.24. Fishing mortality for Celtic Sea by 5 mm size class, estimated by length based VPA.

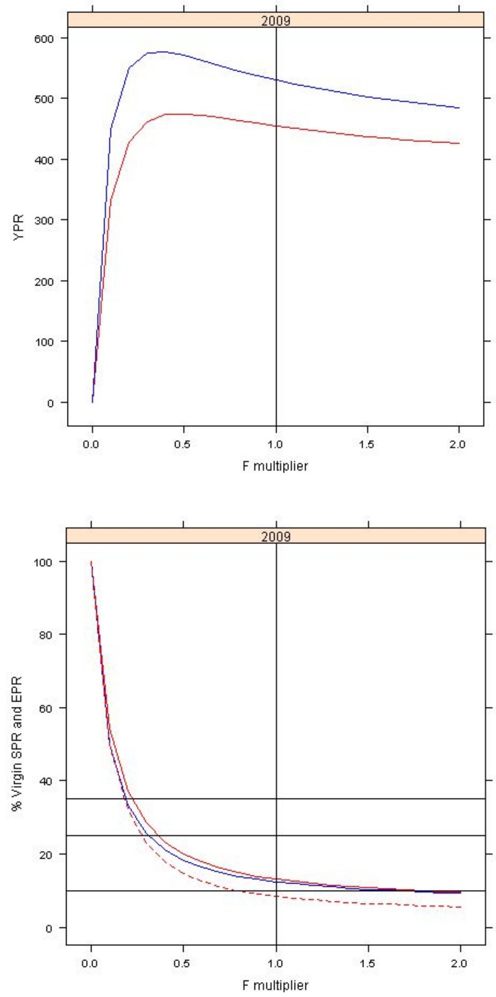

Figure 5.1.25. Celtic Sea yield, spawner and egg per recruit curves assuming M=0.1 with lines indicating reference levels (F_{sq}, 35%, 25% and 10% of virgin SPR and EPR).

Stock status

Table 5.1.12. Celtic Sea summary of stock and fishery performance against reference points.

					Implications of moving to reference point	
Natural Mortality	**Sex**	**Reference point**	**Limit or target**	**Current status**	**Fishing mortality % cut**	**Yield Per Recruit % gain**
0.1	F	F_{max}	T/L	Fsq > Fmax	52	4
		$F_{0.1}$	T		82	-8
		35%VirgSPR	T	13	78	-4
		25%VirgEPR	T	8	73	0
		10%VirgEPR	L	8	21	2
	M	F_{max}	T/L	Fsq > Fmax	64	9
		$F_{0.1}$	T		85	-3
		35%VirgSPR	T	16	81	2
0.2	F	F_{max}	T/L	Fsq < Fmax	-51	9
		$F_{0.1}$	T		62	-6
		35%VirgSPR	T	39	37	4
		25%VirgEPR	T	31	31	5
		10%VirgEPR	L	31	-455	6
	M	F_{max}	T/L	Fsq > Fmax	1	4
		$F_{0.1}$	T		70	-10
		35%VirgSPR	T	46	44	1

Aggregated LPUE has increased from 1984 to 2005 but showed a significant drop in 2006 following the introduction of RSLS. This is due to a larger relative increase in effort than landings in this year. Subsequently the LPUE has recovered and was the highest in the series last year (2009).

Yield per recruit analyses suggest fishing mortality is above levels that would maximise long-term yields when natural mortality is assumed to be 0.1, but when M is assumed to be 0.2 it is at or just above F_{max} for males and below F_{max} for females.

Fishing mortality is also above levels required to meet potential egg and spawner per recruit based targets under both assumptions of M. The EPR limit is achieved at F_{sq} when M =0.2 is assumed, while F is above that required to achieve the EPR limit when M=0.1 is assumed. Moving to the potential target reference points would require substantial reductions in F in most cases. All these F changes result in relatively small changes in YPR.

Irish Sea

Landings and fishing effort

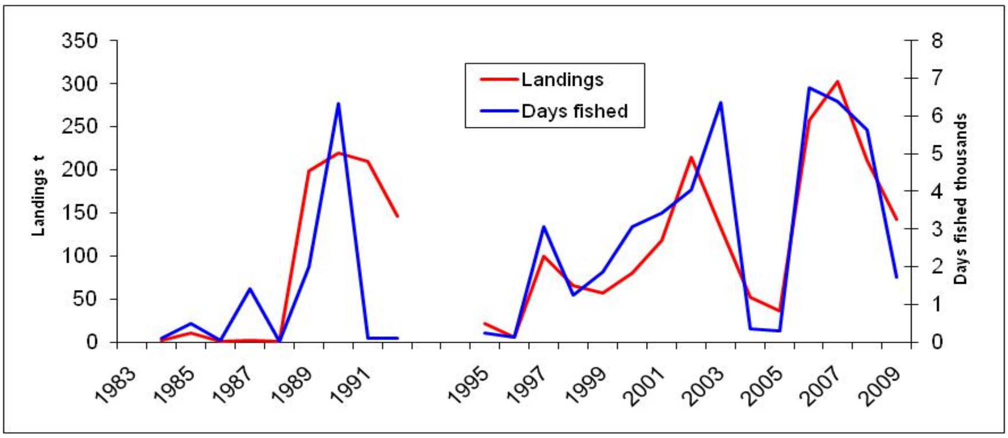

Figure 5.1.26. Time-series of *Cancer pagurus* landings (tonnes: red) and effort (days fished: blue) from the Irish Sea.

Landings per Unit Effort

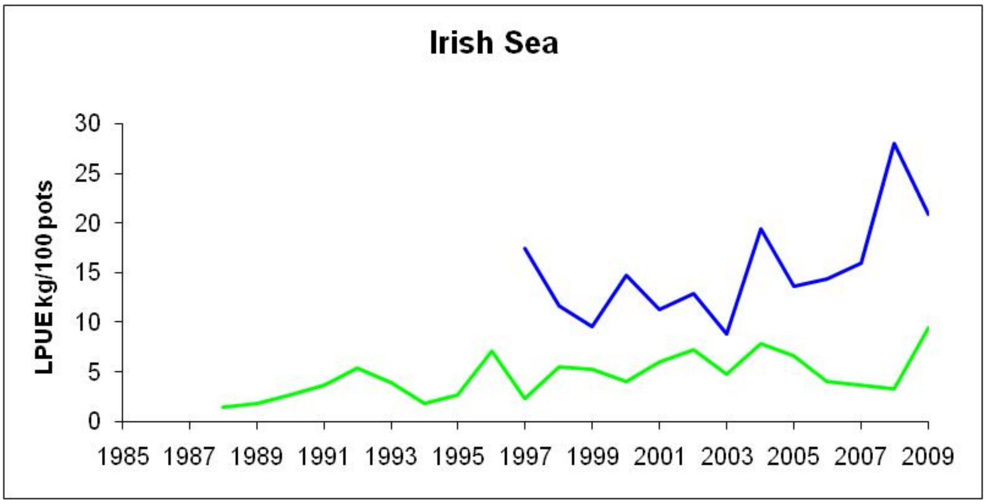

Figure 5.1.27. Time-series of individual vessel *Cancer pagurus* landings per unit effort from the Irish Sea.

Length/width frequency data

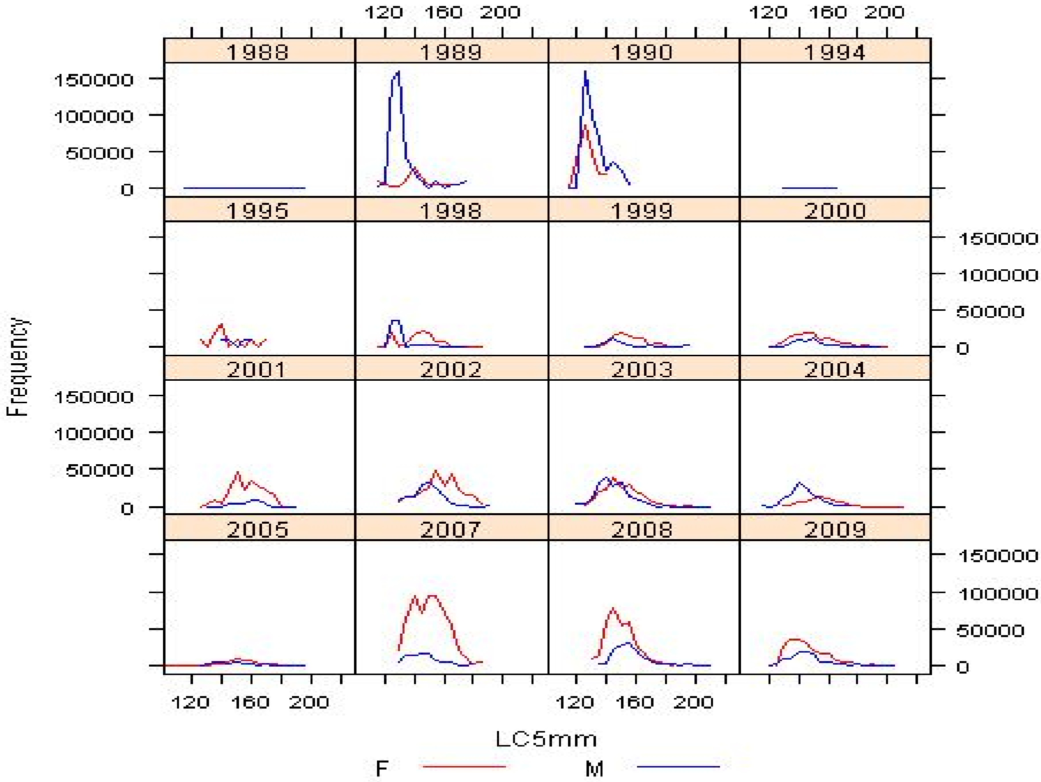

Figure 5.1.28. Time-series of landings raised length distributions for female and male *Cancer pagurus* from the Irish Sea (Note missing years, when no samples were available: <1988, 1991–1993, 1996, 1997, 2006).

Assessment

Because of the paucity of available biological samples for the Irish Sea a length structured assessment has not been presented.

Stock status

LPUE for two vessels show some consistency over some years and marked differences in others. The last year of available data (2009) shows high LPUE for both vessels.

Length distributions are based on very few samples, with no sampling carried out in this area in 2006. Inadequate levels of biological sampling may give rise to biased or unrepresentative length distributions. This problem is particularly acute when low levels of sampling are combined with high raising factors. Low sampling levels are a problem in this area.

5.2 Stock summaries for Scotland

Provided by Marine Scotland Science

Management units /stock units

Scottish waters are divided into twelve assessment units for crabs and lobsters as shown in Figure 5.2.1. These units are based on the previous district and creek system for reporting Scottish landings data, but have been revised to include two offshore areas – Papa, which lies to the west of Shetland, and Sule, which is to the north and west of Orkney and includes the Rona, Sulisker and Sule-Skerry banks.

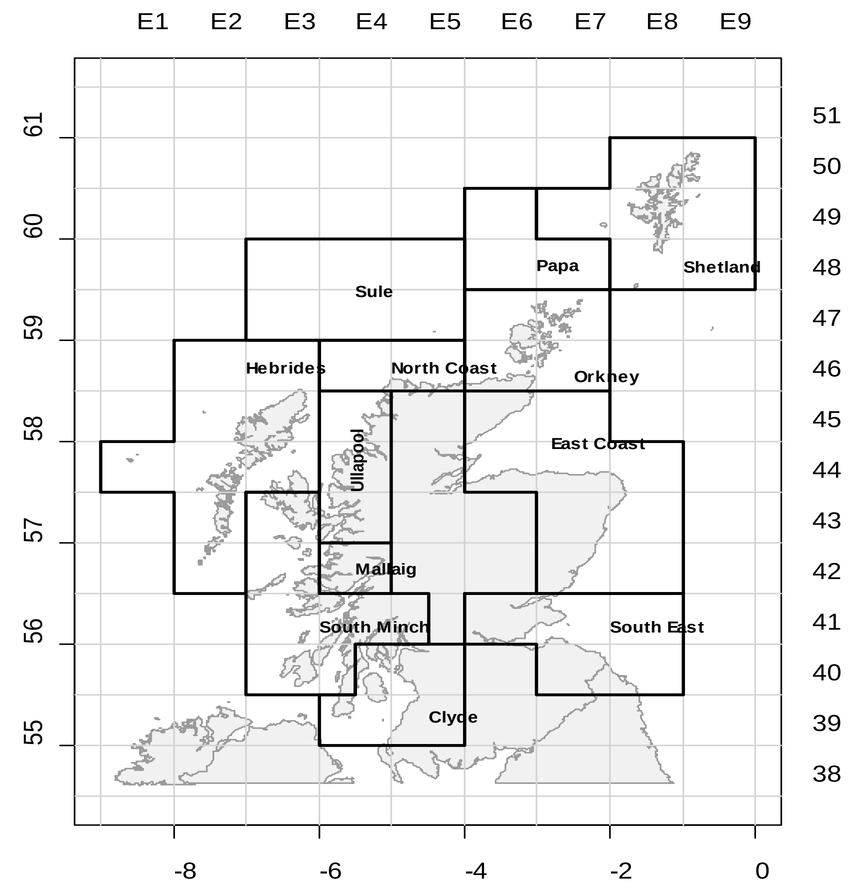

Figure 5.2.1. Crab and lobster creel fishery assessment units in Scotland.

Data by management unit

Landings by unit

Total Scottish landings of *Cancer pagurus* fluctuated between 6700 and 12 000 during 2001 to 2010 (Figure 5.2.2, Table 5 E, page 13). The main fishing areas for *Cancer pagurus* are the Hebrides, Sule, Papa, South Minch and Orkney; landings from these areas account for around 72% of the total. Landings from the offshore areas of Sule and Papa have increased since the mid to late nineties and in 2010 accounted for 26 % of the Scottish fishery. The majority of crabs fished in Scottish waters are landed in the third and fourth quarters of the year.

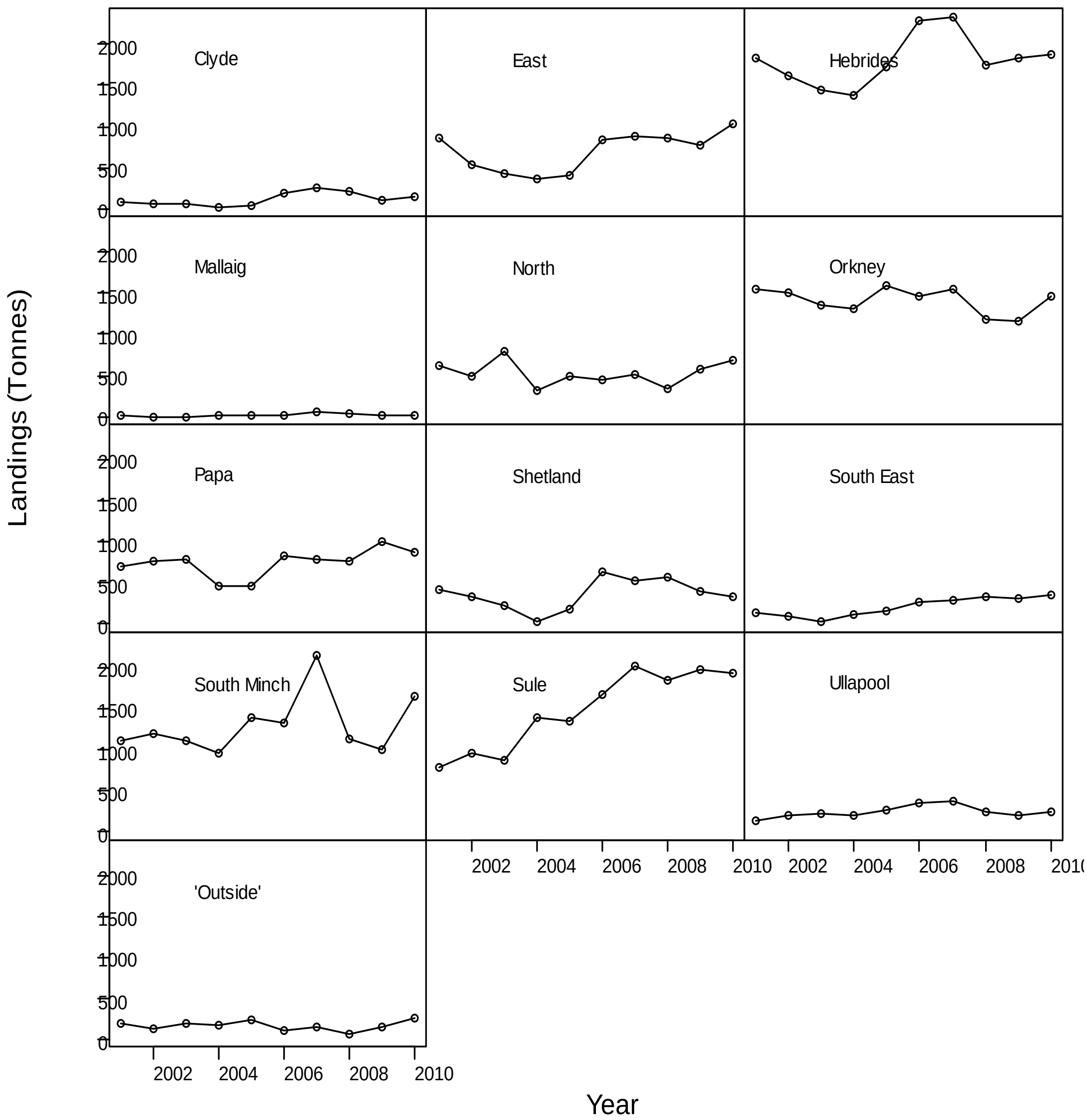

Figure 5.2.2. Annual *Cancer pagurus* landings (tonnes) into Scotland by creel fishery assessment unit 2001–2010. Data from the Fisheries Management Database; 'Outside' relates to *Cancer pagurus* landed outside the creel assessment units; see Figure 5.2.1 for area locations.

Discards

Discards in crab fisheries are sampled only on an irregular basis.

Fishing effort

There are no requirement for creel boats to report the number of creels fished to achieve a standardized measure of catch per unit of effort and the use of "days absent" from port represent only a crude measure of effort that is confounded by the variability of creels fished per day and time taken to get to the fishing grounds. Currently, Shetland is the only area for which fishing effort data are available and routinely collected since the Shetland Regulating order requires licensed fishers to return logbook information detailing catch location and number of creels.

LPUE/CPUE/DPUE – standardised or not?

Data on fishing effort and catch rates are currently lacking. An EU project investigating ways of obtaining better information on catch and effort data through the use of self-sampling and GPS loggers to monitor fishing activity has been carried out. This suggested that indicators of landings-per-unit-effort could be obtained by linking GPS/VMS data and logbook records (Anon, 2010). Detailed information on catch and gears has become recently available for a Vivier crab boat fishing off the West Coast of Scotland that will provide the basis for a LPUE analysis in the future.

Assessment methodology

Length Cohort Analysis (LCA) is used to assess *Cancer pagurus* assessment units in Scottish waters. The LCA method uses the commercial catch size composition data (length-frequency data) and estimates of growth parameters and natural mortality to estimate total stock biomass and fishing mortality at length. The results can be used to predict long-term (equilibrium) changes in the stock biomass and yield-per-recruit based on changes in mortality, fishing effort or minimum size regulations.

Sources of data used in the assessments of *Cancer pagurus* in Scottish waters are described below.

Official landings data

The assessments use official landings data, which detail the location, the species and the weight landed into ports in Scotland. These data are collated by Marine Scotland Compliance from sales notes and EU logbook and Shell 1 forms, and held in the Marine Scotland Fisheries Information Network (FIN) database.

Numbers at length

Length-frequency data are collected by MSS as part of the market sampling programme. The data are held in the MSS Fisheries Management Database (FMD).

Data rising

Length frequency data obtained from market sampling and official landings data are combined to provide a raised annual catch-at-length distribution for input into LCA. This is carried out on a quarterly basis, applying a length-weight relationship to multiply up the length frequency measurements for each sex to reflect the weight of the quarterly landings. The data from each quarter is then combined to give total annual raised length frequencies for each sex. Data sets are averaged over a number of years and aggregated into 5 mm length classes for use in the LCA.

Biological parameters

Information about the growth of *Cancer pagurus* around the UK comes mainly from tagging studies carried out in the 1960s and 1970s (Table 5.2.2). Estimates of the von Bertalanffy growth parameters: asymptotic length (L_∞) and instantaneous growth rate (K), were obtained from Ford-Walford plots. Length-weight relationships (parameters a and b shown in Table 5.2.2) are from Marine Scotland Science (MSS) unpublished market sampling measurements of length and weight.

Table 5.2.2. Biological parameters used in stock assessment for *Cancer pagurus*.

	Growth parameters		Length-Weight relationship		Terminal F	Mortality	Source
	K	L∞	a	b	F	M	
Cancer pagurus							
Males	0.197	220	0.000059	3.214	0.5	0.1	Chapman, 1994
Females	0.172	220	0.000302	2.8534	0.5	0.1	Chapman, 1994

Uncertainties

The LCA approach assumes that the length distribution is representative of a typical cohort over its lifespan. However, this is only true of length frequency data from a single year if the population is in equilibrium and therefore LCA is usually applied to data averaged over a number of years during which recruitment and exploitation rates have been stable. LCA also assumes uniform growth among animals. The approach gives an indication of the exploitation of the stock in terms of growth overfishing, but does not provide any indication of short-term stock dynamics or recruitment over-fishing. It is therefore best to interpret the LCA analyses in conjunction with other information such as catch rate (CPUE) data. The growth parameters used in the LCAs are taken from other studies elsewhere and assumed fixed across all regions (except Shetland). LCA is very sensitive to these parameters and the choice of input parameters may critically influence the results obtained. Differences in size composition across areas suggest that area specific values may be more appropriate. The population structure of *Cancer pagurus* stocks around Scotland is not well understood and improved knowledge of stock identity may lead to a redefinition of the assessment units for *Cancer pagurus*.

Stock status

Assessments based on LCAs for the period 2006–2008 were carried out for nine of the twelve assessment units (a new round of stock assessments will be conducted in 2012). There was insufficient sampling data from the Mallaig, Ullapool and Papa units to conduct LCAs. Of the assessed units, the majority were growth overfished to some extent, particular male stocks. In the units of major importance for *Cancer pagurus* landings, fishing mortality was estimated to be significantly above F_{MAX} for both males and females in Clyde, South Minch and South East whilst in the Hebrides and Sule, current fishing mortality is approximately F_{MAX}. In Orkney, North Coast and East Coast, the fishing mortality for female stocks is close to F_{MAX} while males are being fished above F_{MAX}.

Fisheries Regulations

Vessels landing *Cancer pagurus* in Scotland are required to have a license with a shellfish entitlement. Vessels without this entitlement are only allowed to land limited amounts (25 crabs per day). The main regulatory mechanism is a minimum landing size of 140 mm CW to the north of 56º N and 130 mm CW to the south of 56º N (except for the Firth of Forth).

5.3 Stock summary of the *Cancer pagurus* in France

Provided by IFREMER – Brest

Fishery and landings

Twenty years ago, the number of vessel targeting edible crab was really important along the coast in Brittany and Normandy. Today, less than 30 vessels target the *Cancer pagurus* during a period of the fishing season. These vessels are potters and some of them are also netters. Many other vessels catch edible crab as a bycatch, all the lobster or spider crab potters, all the monkfish netters and the trawlers. For the last, even if the catch by unit effort is low, the high level effort of some fleet lead to significant landings. For the netters, we observe the same situation. Today, around 30% of the landings come from netters and trawlers. In 2010, the official landings reach 5700 tons, but we can suppose, taking in consideration several elements, that the total landings is close to 6500 tons. The main fleet of exclusive potters is composed by twelve offshore potters from 18 to 24 meters. The crew number is 6 in average. The main characteristic of this fleet is its capacity to move and fish in a large area. Indeed, all the traps are stored aboard and the tank capacity is between 14 to 24 tons depending of the boat. All the others vessels targeting edible crab must stay close to their harbour and are then more dependant of the local fluctuation of the abundance.

Today the low number of vessel that is targeting crab in France is mainly due to low market price. For more than 20 years, the price per kilogram has steadily decreased to currently reach a critical level. The economical balance of some vessels is narrow. This situation is explained by the total European landings which continued to increase the last ten years.

The French landings can be considered as stable for fifteen years. We observed some variations but no real trend. The low value in 2009 is an artefact due the modification of the data base (Figure 5.3.1, Table 5 D on page 12).

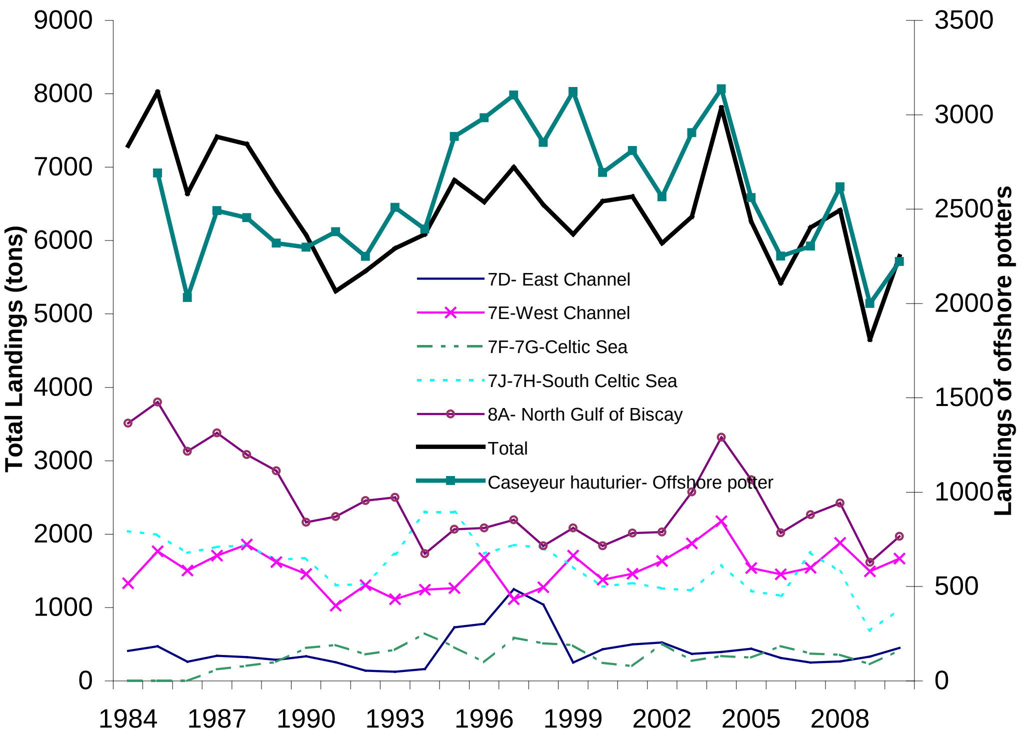

Figure 5.3.1. Historical landings from the different fishing areas in France.

Abundance Index of Crab

The best data currently available are without any problem the fishing declarations of the offshore potter fleet. The quality of these data justifies its use together with the significance of this fleet in the edible crab fishery. Moreover, the vessels of this fleet move in different ICES area provide information on a large part of the stock. Currently, we continue to work to establish new time-series for one or 2 coastal fleets, one in the south west of Brittany and one in Normandy.

In general, the trip of the offshore potters is from 7 to 10 days depending of the tidal coefficient and the weather condition. The number of pot used is from 850 to 1200 per boat. The fishing time by pot is always around 24 hours. Using these data fleet, the time-series represents 26 years with seasonal and spatial information. From these data, a GLM model permits to estimate an abundance index taking in account the different parameters (year, month, area). The base line of the data is per boat, trip, year, month and area, the catch and effort (number of pot used). The four regions considered in the analysis are the Celtic Sea, the Western Channel, the Eastern Channel and the North of the Bay of Biscay.

As the previous analysis, all variables are conserved in the retained GLM model and the cross effect between year and area. For the analysis, all data set is considered in a first hand, then we exclude the months from January to May and December. During this winter period, the activity of the vessels is very irregular in link to very low cpue levels (Figure 5.3.2).

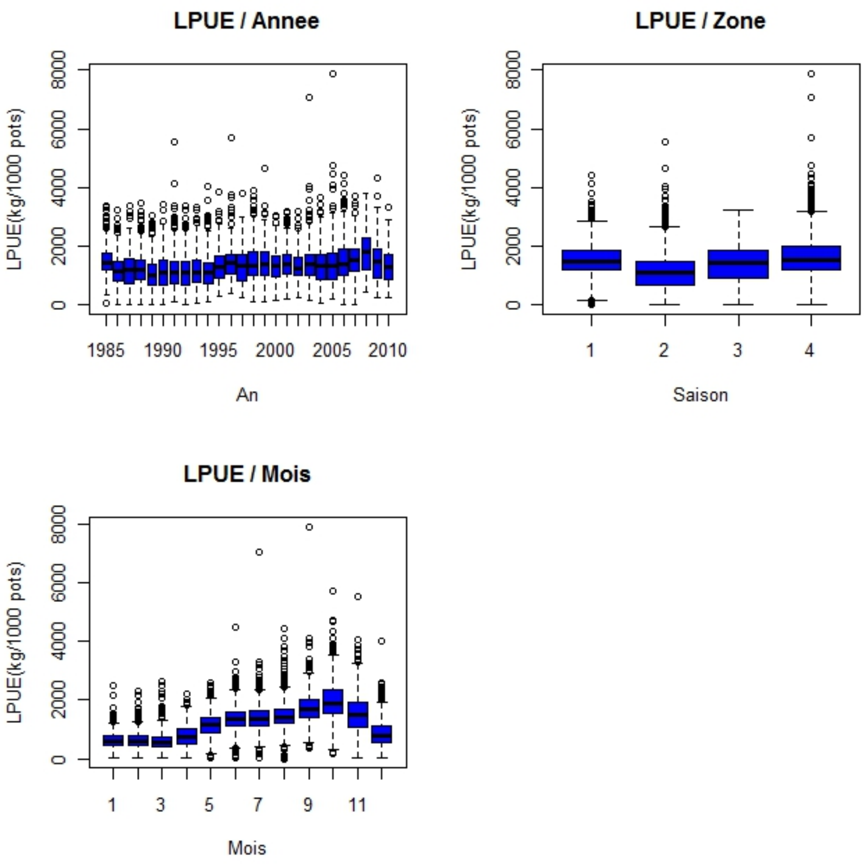

Figure 5.3.2. Development in LPUE using different parameters (Year (An), Area (Saison) and Month (Mois)).

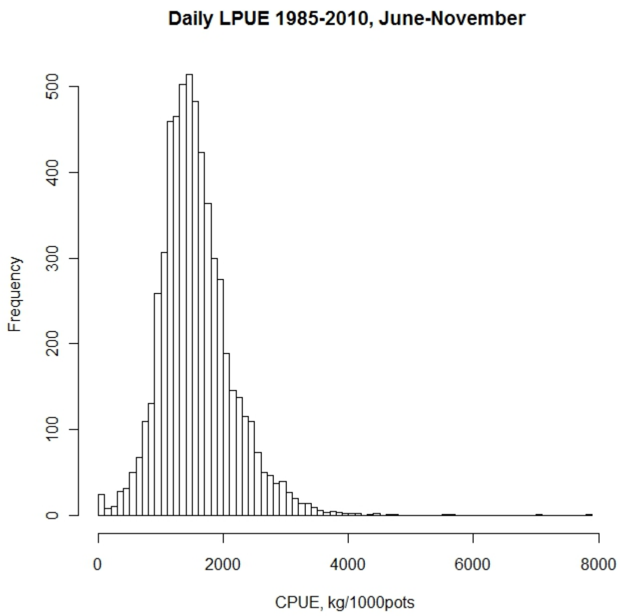

Figure 5.3.3. Frequency of CPUE from the available data set on *Cancer pagurus*.

The distribution of the CPUE (Figure 5.3.3) is close to a normal distribution. So we did not transform the CPUE with a log function for the analysis. We only excluded 4 outliers from the analysis.

For the total data set, the number of trip in the Eastern Channel is too low to really perform a robust analyse. So, we exclude these data and we directly select a restricted data set with monthly data from June to November

The new results show that the trend in 2010 is the same in the three regions, Celtic Sea, Western Channel and Bay of Biscay (Figure 5.3.4) with values close to the average of the time-series, but a little up. For the Western Channel and the Bay of Biscay, the index is quite stable between 2009 and 2010. In contrast, the index decreases a lot in the Celtic Sea. In this region, the abundance is stayed at a high level during 2 years (2008 and 2009).

Over the 20 last years, we observe that the abundance has steadily increased in all regions with a maximum in 2008.

The year 2010 does not change the situation. When we compare the abundance index in the Bay of Biscay and Western Channel (Figure 5.3.4.), the trends are similar. This similarity was previously suggested and the last three years with a huge change in the abundance index and the decrease in 2009 and 2010 in both regions seem to confirm the continuity of the stock from the Western Channel (7E and 7H) to the North of the Bay of Biscay (8A).

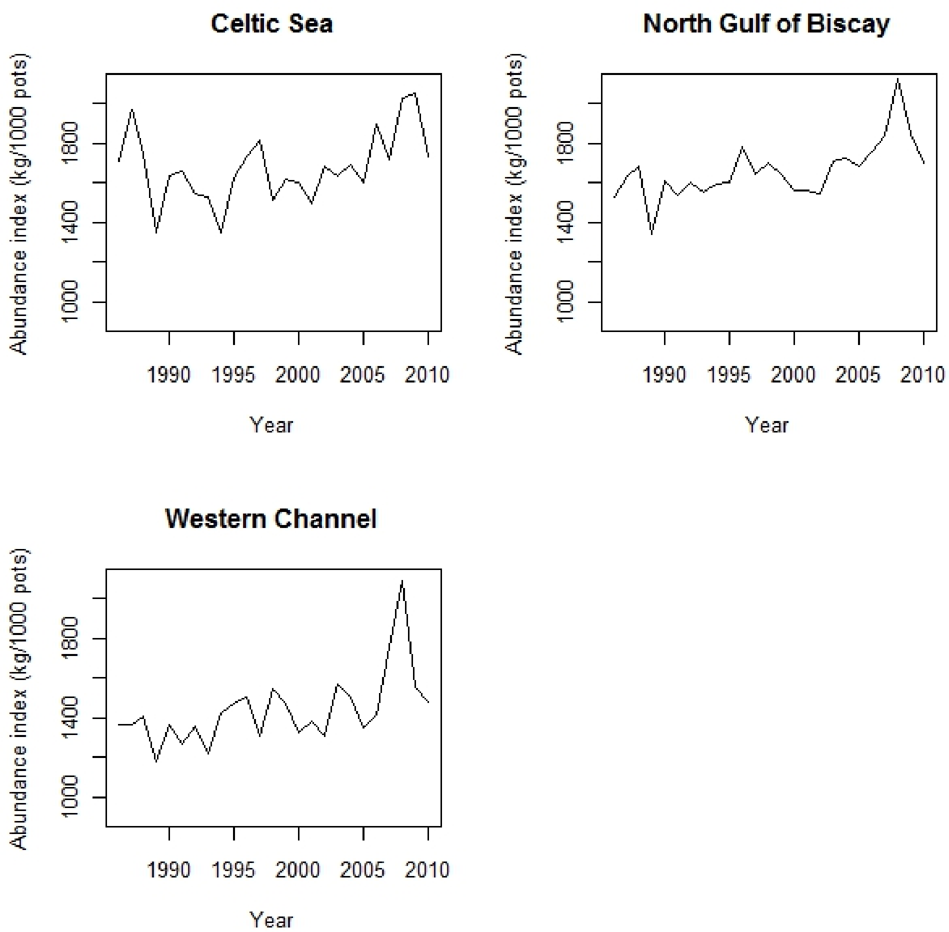

Figure 5.3.4. Abundance index for the three main fishing regions estimated with GLM model.

5.4 Stock summary for Shetland for *Cancer pagurus*

Provided by (NAFC – Scalloway, Shetland)

Background

Detailed fisheries data have been collected for shellfish fisheries around the Shetland Islands, Scotland, since 2000 when a Regulating Order was granted to the Shetland Shellfish Management Organisation (SSMO) in order to locally manage shellfish stocks within the six mile limit. All shellfish vessels are required to fill in logsheets detailing catch, effort, and area fished as part of their licence requirements. This has resulted in a detailed fisheries dataset for those species covered by the order, including *Cancer pagurus* and velvet crab (*Necora puber*). The data presented here show LPUE for these fisheries from 2000 to 2010. Data is also routinely collected in order to carry out Length Cohort Analysis (LCA).

Cancer pagurus fishery

Landings to the *Cancer pagurus* fishery in Shetland have been somewhat restricted by the presence of a single buyer in the islands. At the beginning of the data collection period was an initial fall in landings from around 300 tonnes per year to a minimum of 192 tonnes in 2002 (Figure 5.4.1, Table 5 G, page 16). This was followed by a period of increase to a maximum of 393 tonnes in 2006. In recent years landings have remained between 230 and 290 tonnes. The changes in effort have shown a similar pattern to landings with an initial period of decline where the number of creels lifted almost halved between 2000 and 2003 (Figure 5.4.1, Table 5.4.1). This was followed by a period of increase to a peak in 2006. Effort has remained relatively stable since then.

Although the pattern of change in landings and effort is similar, there is a degree disparity in the scale of change between landings and effort in the *Cancer pagurus* fishery. This resulted in an initial period of relatively stable LPUE of around 0.7 kg/creel between 2000 and 2002, followed by an increase to just under 1 kg/creel between 2004 and 2008 (Figure 5.4.1). Following a marked decrease in 2009, LPUE has risen to 0.86kg per creel in 2010.

Table 5.4.1. Data for the Shetland *Cancer pagurus* fishery; effort (no. of creels lifted) and LPUE (kg/creel).

Year	Effort (no. creels lifted)	LPUE
2000	376048	0.65
2001	345573	0.61
2002	217024	0.65
2003	204315	0.76
2004	223648	0.93
2005	260642	0.93
2006	332949	0.97
2007	300795	0.84
2008	263475	0.94
2009	273035	0.67
2010	297359	0.86

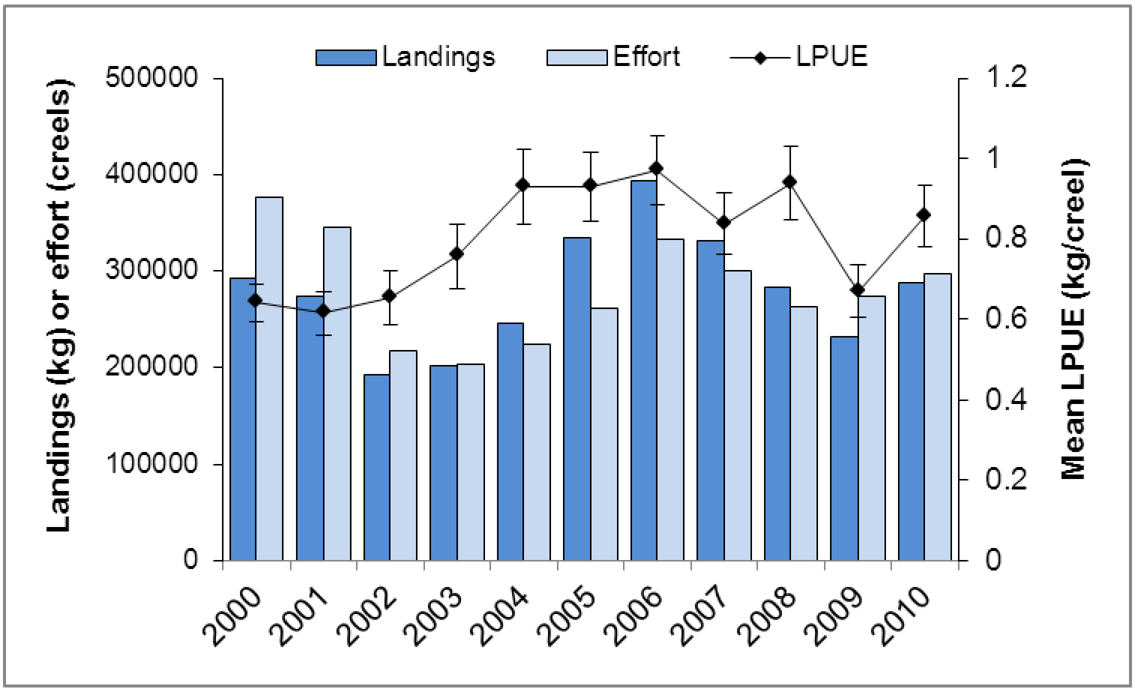

Figure 5.4.1.Total landings of *Cancer pagurus* (kg), total creels catching *Cancer pagurus* and the average LPUE from SSMO logbook data with 95% confidence intervals shown.

A generalised additive model was used to further examine trends in LPUE. All four explanatory variables significantly improved the fit of the model and were retained in the analysis (Figure 5.4.2). Long term trends indicated that LPUE increased from 2000 to 2006, however this has since stabilised and a slight decrease has since been observed. Seasonal effects indicated that LPUE is relatively stable during the first half of the year rising to a peak in September. The area fished as represented by SSMO statistical squares can be seen to have an effect with areas to the west of Shetland having the highest LPUE. As in the previous assessments, large between vessel variations in LPUE were observed. It is also evident that there is a high degree of variability in LPUE for some vessels while for others their LPUE is fairly consistent (Figure 5.4.2). It is likely that those vessels which showed a higher degree of variability in LPUE are those which were not regularly targeting *Cancer pagurus* and therefore their LPUE will have included a component of bycatch of *Cancer pagurus* from the velvet crab fishery. Future changes to the recording of fisheries data in Shetland will allow directed catch and bycatch components to be separated, and a more accurate assessment of LPUE in these multi-species creel fisheries to be determined.

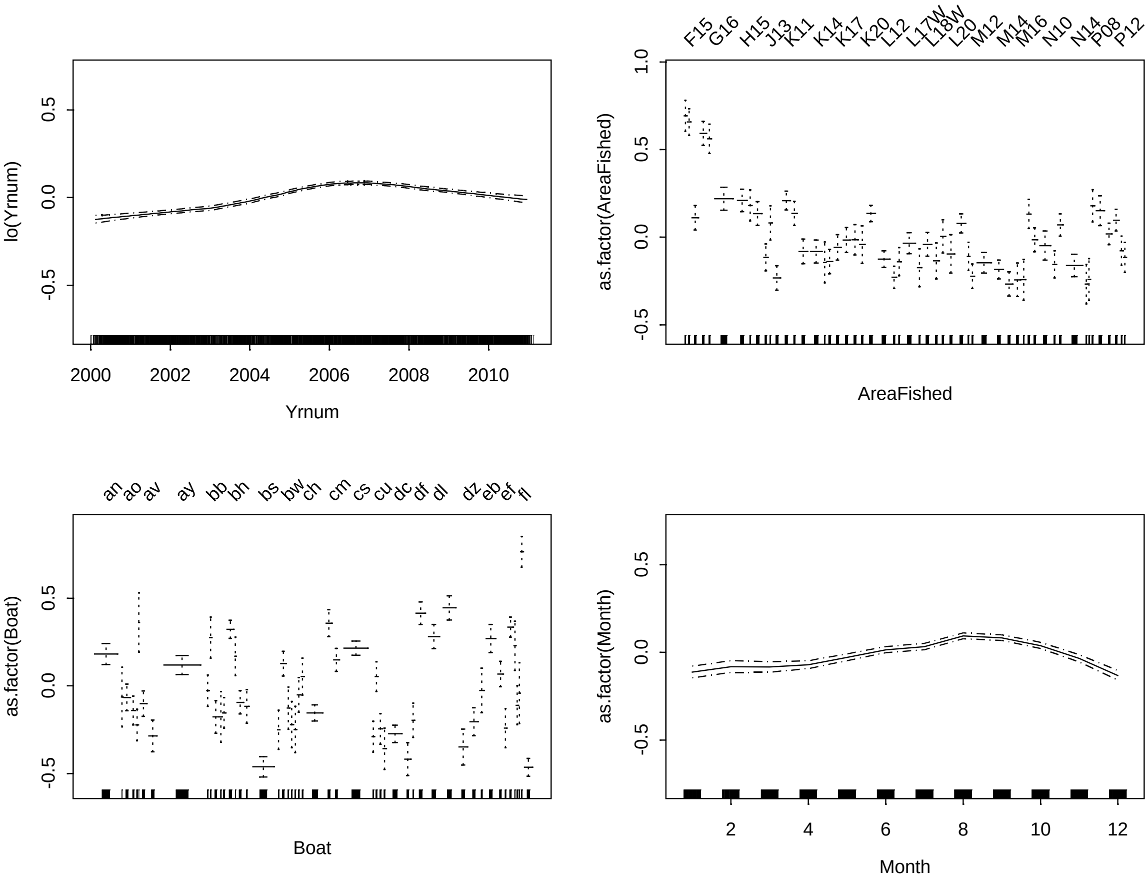

Figure 5.4.2. *Cancer pagurus* diagnostic GAM plots of the fitted curve (continuous line) and factors included in the minimal model. Data are: Yrnum - monthly time-series from Jan 2000 to Dec 2010; Boat - fishing vessel; Area - SSMO statistical square; Month - month of fishing regardless of year, months are represented by numbers commencing with 1 = January. The rug plot at the base of each figure indicates the location of each of the data points fitted for the variable, and the broken lines indicate standard errors.

5.5 Stock status of the *Cancer pagurus* from Norway

Provided by the Norwegian Institute of Marine Research

Management units / stock units

All *C.pagurus* along the Norwegian coast from the Swedish border to West-Finnmark are treated as one stock and there are no separate management units. No genetic investigations have, however, been carried out to verify this assumption. There are regional differences along the Norwegian coast regarding landings, lpue (landings per unit effort), discards, size, and sex ratio. Data are therefore presented separately for seven different assessment units. These assessment units/geographical areas are statistical areas as defined by the Norwegian Directorate of Fisheries (Figure 5.1).

Assessment data

The Norwegian *Cancer pagurus* stock is assessed based on data from a reference fleet, providing data on discards, LPUE (unstandardised), and carapace width in catches (landings/discards) (Table 5.5.1). The reference fleet consists of selected fishers providing data from one fishing trip per week in 10 consecutive weeks. The fishers are equipped with four standard traps with no escape vents (linked into the chain of ordinary traps) from which the following data are recorded:

- CW
- Sex
- Females with external roe (discards)
- Soft crabs (discards)
- Other discards (for instance damaged crabs)
- Total number of traps deployed during that particular fishing trip
- Total catch in kg from that particular fishing trip
- LPUE (kg/standard trap)

There are no data on total fishing effort from the Norwegian crab fleet as there are no logbook data available.

Table 5.5.1. Number of fishers in the reference fleet per statistical area, and total number of crabs caught in the standard traps, 2001–2010.

Statistical area									
Year	8	28	7	6	0	5	4	Total	Total # of crabs
2001			10	8		1		19	20 614
2002	4		9	9		3		25	29 831
2003	4		9	9		3		25	27 028
2004	3		6	9		1		19	7 875
2005			3	7		1		11	7 515
2006			4	8	2	1		15	5 169
2007	4		4	6		1		15	7 135
2008	1		2	4		1		8	3 778
2009	3		1	1				5	2 966
2010	2	2	3	3				10	4 769

Landings

The Norwegian landings of edible crab increased from 2009 to 2010, and then decreased again in 2011 (preliminary numbers). The landings are still on a high level.

Crabs are probably sold unregistered in all of Norway. From 2010 onwards all crabs sold to consumers in area 9 must be reported.

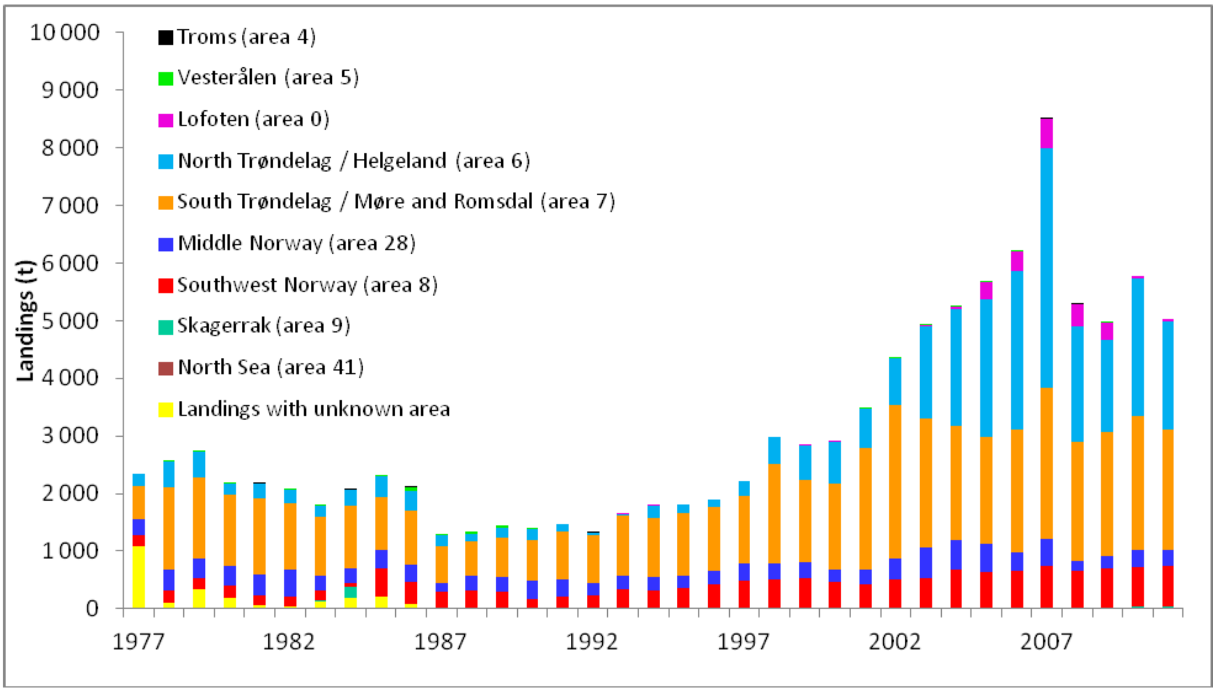

Figure 5.5.1. Norwegian landings of *Cancer pogurus* per statistical area, 1977–2011. The 2011– data are until November. Data from the Norwegian Directorate of Fisheries.

State of the stock

Due to few fishers in the reference fleet in 2008 and 2009 the LPUE-data from these years are uncertain. For some statistical areas the index is based on data from only one fisher, and for some statistical areas data are lacking. The data situation improved somewhat in 2010, but there are still data lacking from some statistical areas. Due to long distances from fishing areas to landing ports two crab fishers in areas 0 (Vestfjord) and 5 (Vesterålen) did not fish in 2010.

It is therefore difficult to say something certain about the total stock development. Stock indicators (LPUE, mean CW of landings) indicate a stable or increasing stock (Figures 5.5.2, 5.5.3). The drop in LPUE in area 6 in 2009 was due to sales organization introducing a MLS of 14 cm this year. This arrangement was not continued in 2010. The legislated MLS is 13 cm.

Discard rates vary from year to year and between areas. The rate of discards is generally lower in the northernmost areas (areas 0 and 5), but data are unfortunately lacking from these areas the last years (Figure 5.5.4). In areas further south more than half the catch may be discarded (soft crabs, females with external roe, specimens below MLS).

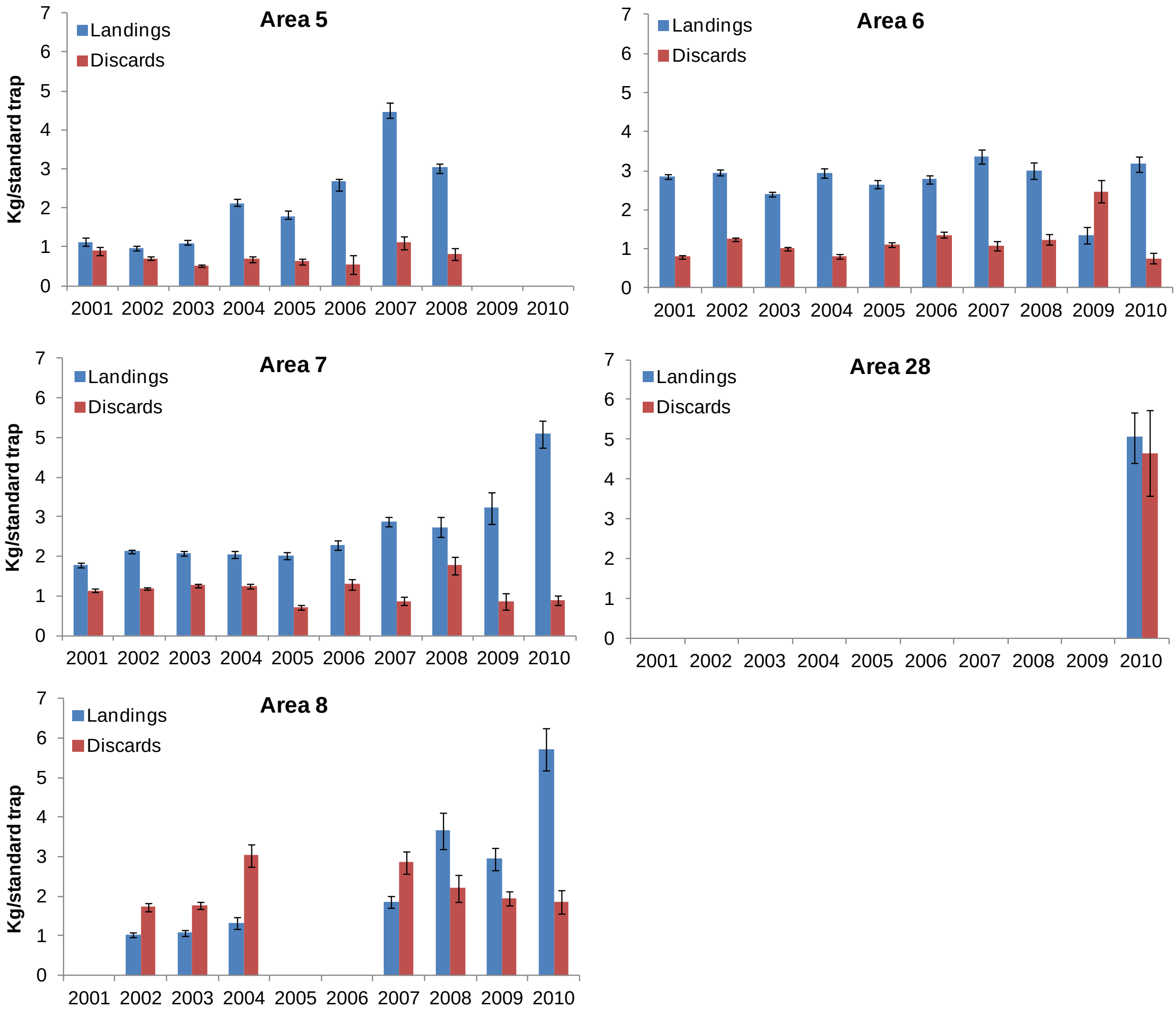

Figure 5.5.2. Indices of LPUE and discards per unit effort (standard trap) from the reference fleet of crab fishers, given per statistical area (Figure 5.1) for 2001–2010.

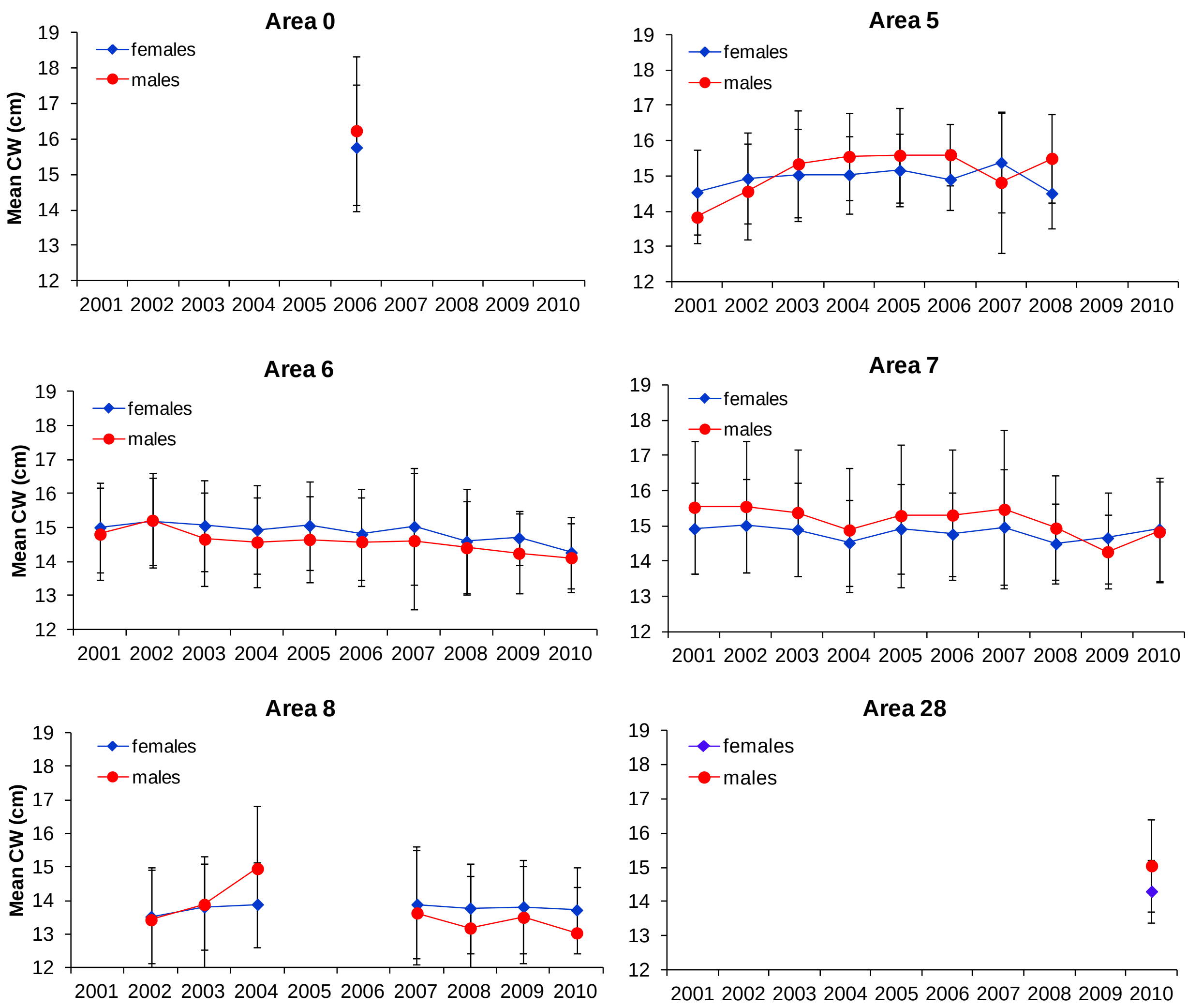

Figure 5.5.3. Mean CW of males and females in landed catch from the reference fleet of crab fishers, given by statistical area (Figure 5.1) for 2001–2010.

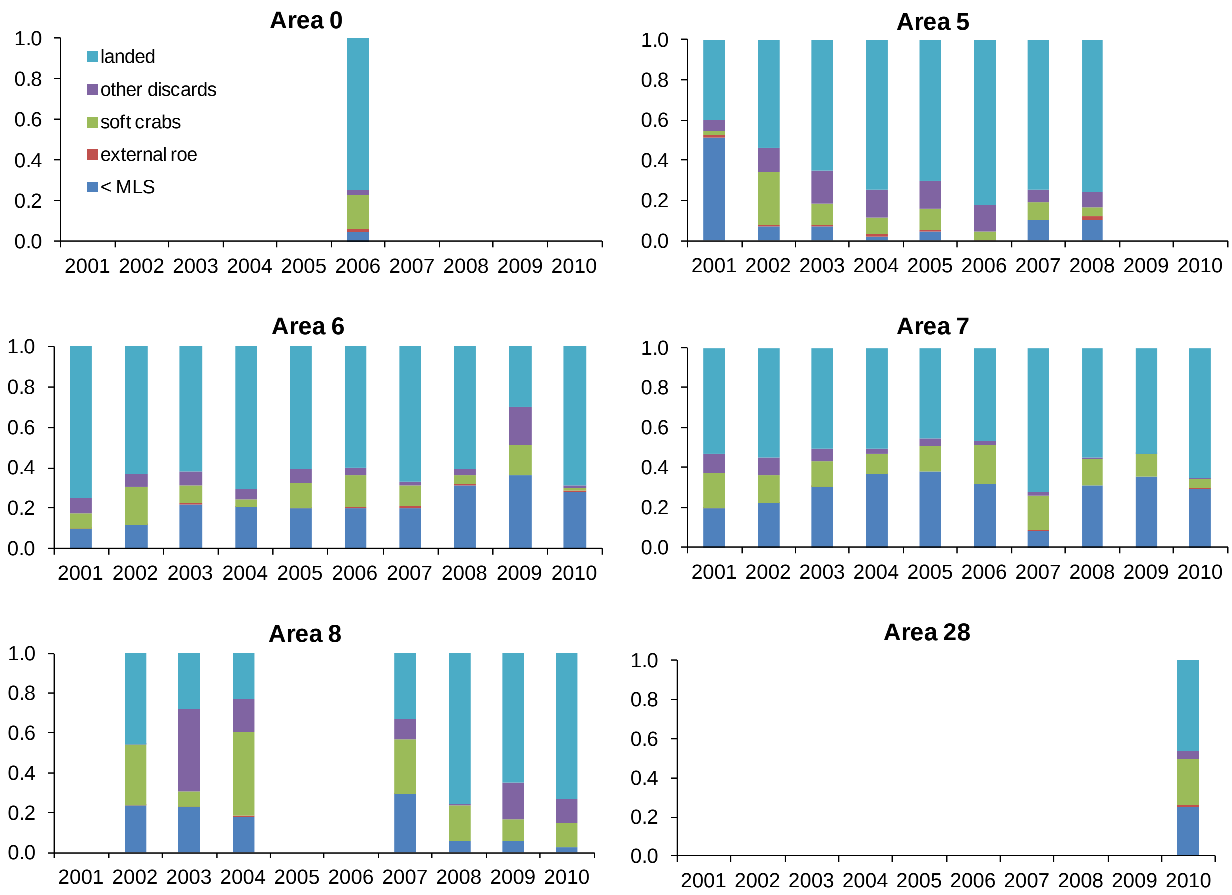

Figure 5.5.4. Proportions of landed and discarded catch from the reference fleet of crab fishers, given by statistical area (Figure 5.1) for 2001–2010.

6 Red king crab (*Paralithodes camtschaticus*)

6.1 Stock status of the red king crab (*Paralithodes camtschaticus*) in Norwegian waters

Provided by the Institute of Marine Research

Assessment units

The introduced red king crab is extending its distribution continuously and is now occupying significant parts of the southern Barents Sea. The broadest distribution is in the Russian zone extending eastwards along the Kola coast to the Koguljev Island. There is also a notable off shore distribution in the Russian part, which is not the case in Norwegian waters. In Norway, the core distribution goes west to about 25° E, with some single catches further south and west (Figure 6.1.1). Since 2007, the red king crab is managed separately between Norway and Russia; regarded as one stock in Russian and one in Norwegian waters.

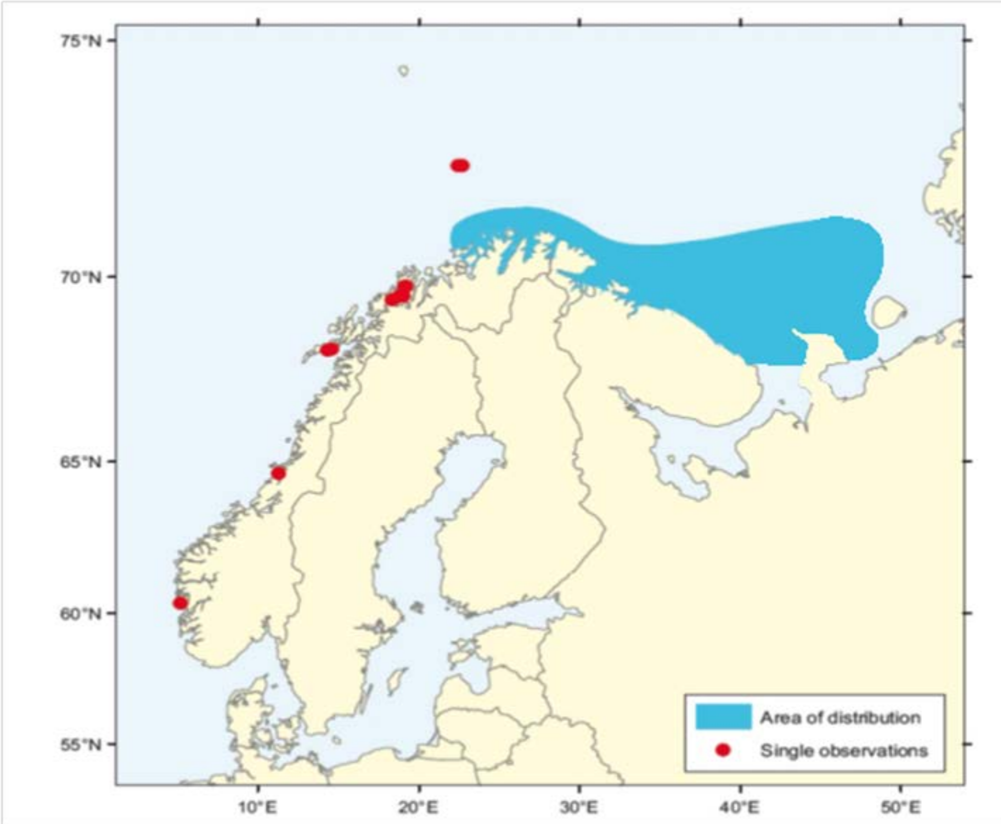

Figure 6.1.1. Current geographical distribution and single observations of red king crab.

Data sources, assessment methods and management regulations

Information on the available indicators, assessment methods applied, data sources, biological parameters in models and types of output generated are presented in Table 6.1.1. Current management measures are presented in Table 6.1.2. For future discussions on the red king crab it would be of great use if Russian scientists attended future meetings of the WG.

Table 6.1.1. Summary of available fisheries indicators, analytical assessments used data sources, biological parameters and output from assessment for the Norwegian red king crab.

	Norway
Number of stocks in which national fleet is active	
Stock areas (cross reference to map)	
	ICES Area 03
Indicator	
Landings	1994–2010
Effort	1994–2010
LPUE	
DPUE	
Size frequency data	
Others	
Analytical assessment methods	
LCA	
Production	yes
Change in ratio	
Depletion methods	
Data sources	
Surveys	
Larval	
Juvenile index /biomass	
Adult index/biomass	annual
Non target surveys	
Commercial	
Observer/self reporting/reference fleet	
Size frequency data	
Logbooks	yes
Tag returns	
VMS	
Electronic logbooks	
Biological parameters	
M	0,2
Growth data	incerment and moulting frequency
Fecundity	yes
Size at maturity	110
Analytical assessment outputs	
Biomass	yes
Spawning stock	yes
Recruitment	yes
Fishing mortality	yes

Table 6.1.2. Management measures for red king crab in Norway.

Management measures	Norway
Licensing	yes
Limited Entry	Yes
Closed seasons	no
Days at sea	No
Closed areas	No
Minimum size	130 mm
Maximum size	no
Berried female legislation	no
Soft crabs	no
Single sex fishery	no
Vessel size	22 m
Vessel power	
VMS (AIS)	yes
Log book returns	yes
Trap limits	yes
Trap size	no
Escape vents	yes
Biodegradable panels	no
Others	

Landings

Landings for the period 1995 to 2010 show an increase in exploitation of the red king crab resource over the recent years in line with management plans (Table 6.1.3.)

Table 6.1.3. Landings of red king crab from 1995 to 2010. N.B. Catches from 1995–2008 are given in number of crabs (x 1000), and in 2009 and 2010 catches are given in tones.

YEAR	Catch in quota regulated area	Catch in free fishing area
1995	11	
1996	15	
1997	15	
1998	25	
1999	37,5	
2000	37,5	
2001	100	
2002	100	
2003	200	
2004	280	
2005	280	
2006	300	
2007	300	
2008	679	
2009	1185 t	4915 t
2010	936 t	969 t
2011	1370	354

Summary of assessment for the red king crab (*Paralithodes camtschaticus*)

Fishery and management

Management of the red king crab in Norwegian waters has two main goals, (a) to obtain a predictable long term harvest in a limited geographical area (Commercial area), and (b) to limit the spread of the crab beyond this limited area (Unrestricted fishery area). Up until April 2010, the commercial area was limited to all coastal areas east of 26° E and inside 12 nm from the coast. In Porsangerfjord there was an additional unrestricted fishery area south of a fixed line about half way inside the fjord. In May 2010 new borders for the commercial area were changed to all areas east of 26° E and south of 71° 30′ N. The commercial fishery is regulated by TAC and vessel-quotas, and only male and female crabs larger than 130 mm carapace length are legal for catch.

In 2009 landings of king crabs were significantly higher from the unrestricted area than from the commercial area. This was due mainly to high landings of both male and female crabs of all sizes larger than 0.8 kg in the unrestricted areas. In 2010 the catches in the unrestricted areas decreased substantially, and are slightly higher than in the commercial area. From a management point of view the unrestricted fishery was aimed to limit the spread of the king crab further west along the coast of northern Norway. However, since there was little interest among the industry for crabs smaller than 0.8 kg, these were discarded by the fishermen – usually fully viable. Therefore, Norwegian government launched a decimating fishery west of 26° E where the fishermen were paid for all crabs they were able to land. This arrangement has taken place in 2010 and 2011, and surveys west of 26° E have proved this to be an effective way of limit further spread westwards.

Surveys and assessment

The king crab stock in the commercial area is surveyed yearly during autumn. There is one cruise in the four fjords where crab density is obtained using a specially designed crab trawl. In addition traps are used to investigate areas where it is not possible to trawl and to increase the number of crabs that are available for measurement of size and sex composition. Only traps are used in the open sea areas to attain figures for crab densities. Stock indices are established using two different mathematical approaches due to the problem with "0 – samples". Previously all data were log-transformed to handle the zeroes, but recently a Bayesian probability approach is used to handle these zeroes which are independent of the magnitude of the density figures.

Assessment approaches to the red king crab stock

As noted above, management of the red king crab in Norway has two main objectives; 1) to sustain a predictable fishery at a certain level within a limited geographical area, and 2) to prevent further dispersal of the crab westwards along the coast and northwards into the Barents Sea. A MSY–approach in the assessment is therefore questionable. Since 2010 the MSY-concept as an assessment tool for the advice for harvest on this stock, has been rejected.

Stock indices and exploitation rate

Both the total crab stock as well as legal male and spawning stock indices decreased from 2010 to 2011. This is probably caused by heavy overfishing in recent years, but in 2011 low indices may also be caused by sampling problems during the cruise. However, the size distribution of the crab in different parts of eastern Finnmark confirms partly this observation revealing very few crabs larger than 130 mm carapace length (MLS). Exploitation rates of legal male stock in the Norwegian king crab fishery have increased substantially in recent years from about 30% in 2007 to about 90% in 2011. Almost all catches of crabs today therefore consist of recruits. Stock indices of pre-recruit I and II in 2011 is at a medium level and there are no signs of numerous year classes in any areas in Norwegian waters.

Conclusions

The decrease in all king crab stock components in recent years entails lower future fishing quotas if today's minimum legal size is maintained. In order to meet the objective to limit the spread of the crab further westwards, increased exploitation rates and a lower minimum legal size is probably necessary.

7 Snow crab (*Chionoecetes opilio*)

Information was presented at the WG from Canadian snow crab fisheries and from the French territory of St Pierre et Miquelon. In addition, Greenland scientists presented status for the snow crab at West Greenland.

In Canada, snow crab stocks areas have been defined by fisheries managers and stocks are therefore assessed at the defined spatial scale. These management units are shown in Figure 7.1.1,-3,-5 and -7, and the French fishery of St Pierre et Miquelon is based in area 3PS in southern Newfoundland. Greenland snow crab fisheries data are aggregated into 6 assessment units which are the basis for management (Figure 7.1.2).

Landings in Canada reached a peak in 2002 with 105 629 t and oscillating around 90 000 t since then. The highest landings in St. Pierre et Miqueron were recorded in 1999 reaching 589 t but fluctuating below the 200 t level since 2002. Landings in Greenland were reached a peak in 2001 with 15 139 t but a decreasing trend is observed since then recording around 2000 t in 2010 (Table 7.1.1).

Table 7.1.1. Annual landings of snow crab from north-western Atlantic (Canada, St. Pierre et Micheron and Greenland).

	Canada	St. Pierre & Miqueron	Greenland
Year	Landings (t)	Landings (t)	Landings (t)
1995	65 495	1	997
1996	65 500	189	563
1997	71 388	368	3214
1998	73 262	354	2094
1999	94 788	589	4982
2000	92 888	550	10521
2001	94 571	485	15139
2002	105 629	139	11174
2003	96 016	83	7179
2004	102 635	159	6295
2005	93 380	157	4213
2006	89 051	191	3305
2007	90 171	166	2189
2008	93 302	123	2354
2009	96 976	169	3191
2010	83 684	236	1621

All 2010 data are preliminary.

7.1 Canadian Snow Crab (*Chionoecetes opilio*) Stock Summary

Provided by DFO, Moncton

The snow crab (*Chionoecetes opilio*) is a circumpolar species that supports fisheries in the north Pacific and north Atlantic Oceans. Fisheries in the northwest Atlantic are prosecuted on the Newfoundland and southern Labrador Shelf, in the Gulf of St. Lawrence, and on the eastern Nova Scotian Shelf. All snow crab fisheries prosecute only males. Females cease moulting when they attain sexual maturity at sizes smaller than the minimum legal size, set at 95 mm carapace width (CW) for Canadian fisheries. Fisheries have been managed by fishing season, fishing effort (number of licence and trap), inhibition of landing newly-moulted crab, and quota. The current fishing and stock status in four different administrative zones (Newfoundland, Nova Scotian Shelf, Northern and southern Gulf of St. Lawrence) are as follows:

Newfoundland and Labrador (2G,H,J: 3K,L,M,N,O;3Ps, Pn; 4R)

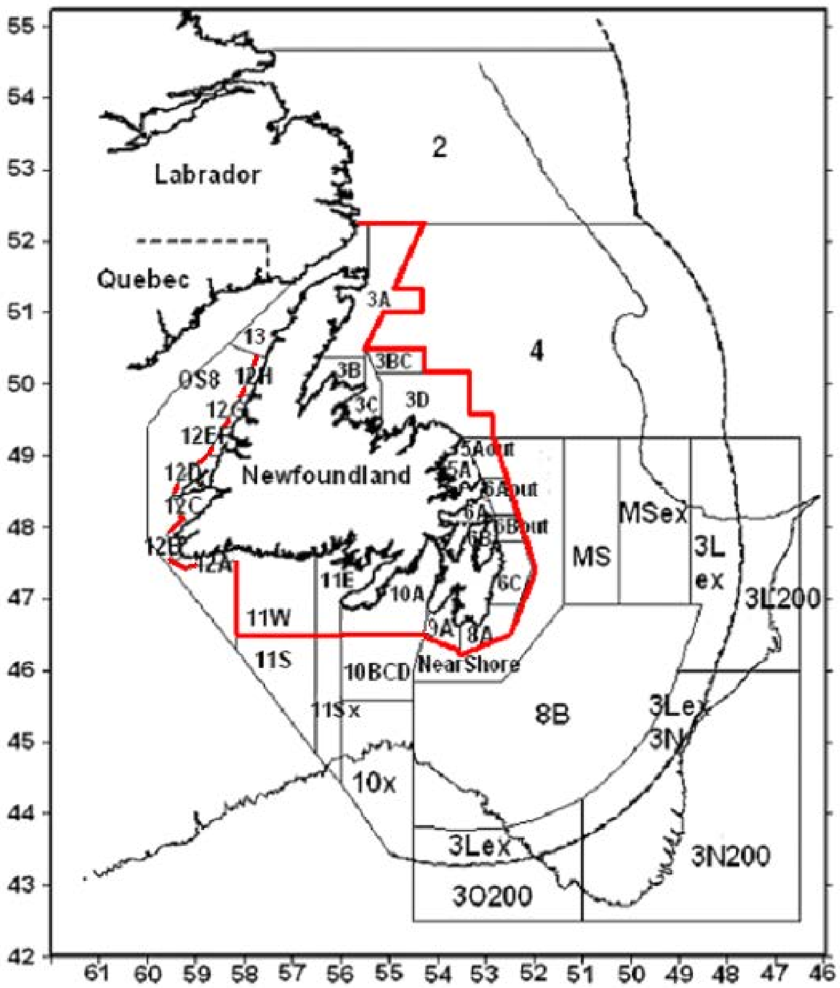

Figure 7.1.1. Snow crab fishing areas in Newfoundland and Labrador Region.

General stock summary

- Total landings increased by 22% from 44 000 t in 2005 to 53 500 t in 2009, but then decreased to 52 200 t in 2010, primarily due to a decrease in Div. 3K.
- The multi-species trawl surveys indicate that the exploitable biomass increased from 2003–2007 due to recovery in the south (Div. 3LNOPs) while the north had decreased (Div. 2HJ3K). There has since been little change.
- Recruitment increased from 2003–2008 and has since changed little.
- Longer-term recruitment prospects are uncertain.

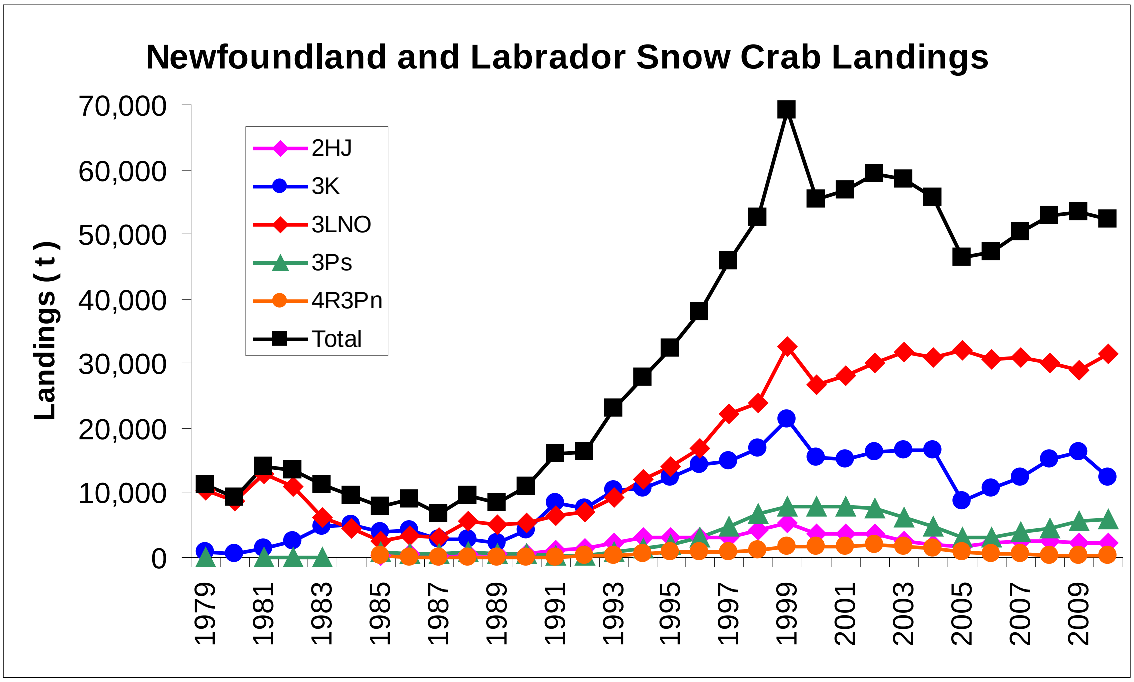

Figure 7.1.2. Annual historical landings of snow crab between 1979 and 2010 by NAFO division in Newfoundland and Labrador Region.

Division 2H

- Landings declined by 63% from 190 t in 2007 to 70 t in 2010.
- CPUE decreased from 2006–2009 and was unchanged in 2010.
- The exploitable biomass changed little from 2008–2010. The post-season trawl survey exploitable biomass index peaked in 2006, decreased by 68% to 2008, and remained unchanged in 2010.
- Recruitment has decreased since 2004 and is expected to be low over the next several years. There were no pre-recruit males captured in the 2010 post-season trawl survey.
- Maintaining the current level of fishery removals would likely result in little change to the exploitation rate in 2011, but would increase the exploitation rate in future years.

Division 2J

- Landings increased by 60% from 1500 t in 2005 to 2400 t in 2008. They decreased by 14% to 2100 t in 2010. Effort increased by 27% in 2009 and changed little in 2010.
- CPUE increased from 2004–2007 and changed little until it decreased sharply in 2010.
- The exploitable biomass has decreased in recent years. The post-season trawl survey exploitable biomass index peaked in 2006, declined to 2009, and changed little in 2010.
- Recruitment has recently declined and is expected to remain low in the short term. The post-season trawl survey pre-recruit index was exceptionally high in 2004 and has otherwise fluctuated without trend since 1999.

- The exploitation rate index declined between 2003 and 2007 but has since gradually increased. The pre-recruit fishing mortality index declined sharply between 2003 and 2005, and has since remained low.
- Maintaining the current level of fishery removals would likely have little effect on the exploitation rate in 2011.

Division 3K Offshore

- Landings more than doubled from 6000 t in 2005 to 12 600 t in 2009 but decreased by 24% to 9600 t in 2010 (13% below the TAC). Meanwhile effort changed little until it increased by 73% in 2009 before decreasing by 15% in 2010.
- CPUE declined sharply since 2008.
- The exploitable biomass, as indicated by the post-season trap and trawl survey indices, declined by about half since 2008.
- Recruitment decreased in 2010 and is expected to change little in 2011. Prospects remain poor in the short term. Post-season pre-recruit biomass indices from both trap and trawl surveys have declined by 34–52% respectively since 2008.
- The trawl survey exploitation rate index declined sharply between 2006 and 2009 and has since increased back to the 2006 level. The pre-recruit fishing mortality index increased from 2006–2009 and changed little in 2010.
- Maintaining the current level of fishery removals would likely result in an increase in the exploitation rate and high mortality on soft-shelled immediate pre-recruits in 2011.

Division 3K Inshore

- Landings increased by 33% from 2700 t in 2005 to 3600 t, in 2009, but dropped by 22% to 2800 t in 2010 (16% below the TAC). Effort has increased by 67% since 2008.
- CPUE increased sharply from 2005 to a record high level in 2008, but has since declined by half.
- The exploitable biomass, as indicated by the post-season trap survey index, decreased gradually between 2007 and 2010 but there is considerable variability among management areas.
- Recruitment prospects, as indicated by the post-season trap survey index, have improved slightly, but there is considerable variability among management areas.
- It was not possible to estimate the exploitation rate index in 2010 because of uncertainty concerning the 2009 exploitable biomass index. Data are insufficient to estimate pre-recruit mortality rates.
- It is not possible to infer how maintaining the current level of removals would affect the exploitation rate in 2011. However, it would likely result in increased wastage of soft-shelled immediate pre-recruits in 2011.

Division 3LNO Offshore

- Landings remained at 22 000–25 000 t since 2000. Effort increased steadily from 2000–2008 and has since declined by 16%.

- CPUE declined steadily from 2000–2008, to the lowest level since 1991, but has increased during the past two years.
- The exploitable biomass has recently increased. Both the trap and trawl survey exploitable biomass indices increased sharply in 2009. The trap survey index increased further in 2010, while the trawl survey index decreased. However, both indices remain above 2005–2008 levels.
- Both post-season surveys indicate that recruitment has been recently increasing. Prospects remain promising for the next two to three years, as both the trap and trawl survey pre-recruit biomass indices have remained at high levels since 2007.
- Both the exploitation rate index and the pre-recruit fishing mortality rate index peaked in 2008 and have since declined. The latter index was near its lowest level in 2010.
- Maintaining the current level of removals would likely have little effect on the exploitation rate in 2011.

Division 3L Inshore

- Landings increased by 19% from 6100 t in 2005 to 7300 t in 2010. Meanwhile, effort decreased by 23% from 2005–2008, and has subsequently increased by 21%.
- CPUE has changed little during the past four years and remains near the long-term average.
- The post-season trap survey index indicates the exploitable biomass has changed little over the past 7 years.
- Overall, recruitment prospects have recently improved, but there is considerable spatial variability.
- The exploitation rate index from the post-season trap survey has varied without trend since 2005. Data are insufficient to estimate pre-recruit fishing mortality index.
- Maintaining the current level of fishery removals would likely result in little change in the exploitation rate, but may increase mortality on soft-shelled immediate pre-recruits in some areas in 2011.

Subdivision 3Ps Offshore

- Landings increased by 70% from 2300 t in 2006 to 3900 t in 2010. Meanwhile effort decreased from 2006 to 2008 and increased slightly to 2010.
- CPUE increased from 2005–2009 and changed little in 2010.
- The exploitable biomass, as indicated by both the spring trawl survey and the post-season trap survey indices, increased steadily from 2006–2009 and decreased slightly in 2010.
- Recruitment appears promising for 2011 but is expected to decline thereafter.
- Exploitation and pre-recruit mortality rates, as indicated by spring trawl survey indices, decreased from 2007–2009 but increased in 2010.
- Maintaining the current level of fishery removals would likely have little effect on the exploitation rate in 2011.

Subdivision 3Ps Inshore

- Landings increased from 700 t in 2005 to 2200 t in 2010 while effort declined slightly.
- CPUE has increased steadily from 2005 to its highest level since 1996.
- The exploitable biomass, as indicated by the post-season trap survey index, increased substantially between 2006 and 2008 and has since changed little.
- Recruitment has recently increased and prospects for 2011 and 2012 are promising.
- The post-season trap survey-based exploitation rate index changed little during 2008–2010. Data are insufficient to estimate a pre-recruit fishing mortality index.
- Maintaining the current level of fishery removals would likely have little effect on the exploitation rate in 2011.

Division 4R Offshore

- Landings declined by 83% from 190 t in 2007 to a historical low of 30 t in 2010, while **effort** declined by 91%. The TAC has not been taken since 2002.
- CPUE declined slightly from 2006–2009 but increased sharply in 2010. However, the 2010 increase was associated with a record low level of both landings and effort.
- The exploitable biomass is low as reflected by virtual abandonment of the fishery in recent years. The post-season trap survey index decreased in 2009 and was unchanged in 2010.
- Recruitment has been low in recent years and prospects for the short term are poor.
- The time-series of information from the post-season trap survey is insufficient to interpret any trend in the exploitation rate index. Data are insufficient to calculate a pre-recruit fishing mortality index.
- Maintaining the current level of fishery removals would likely result in little change to the exploitation rate in 2011.

Division 4R Inshore

- Landings and effort were at historical lows in 2010. Landings declined by 90% from 950 t in 2003 to 190 t in 2010, while effort declined by 60%. The TAC has not been taken since 2002.
- CPUE declined steadily from 2002 to its lowest level in 2008 and has changed little since.
- The post-season trap survey exploitable biomass index changed little between 2005 and 2009 but increased in some management areas in 2010.
- Recruitment has recently increased. Prospects remain promising for the next two to three years, but there is considerable variability among management areas.
- The post-season trap survey exploitation rate index has changed little since 2005.
- Increased fishery removals would not likely increase the exploitation rate in 2011, but may increase mortality on soft-shelled immediate pre-recruits in some management areas.

Scotian Shelf (4VWX)

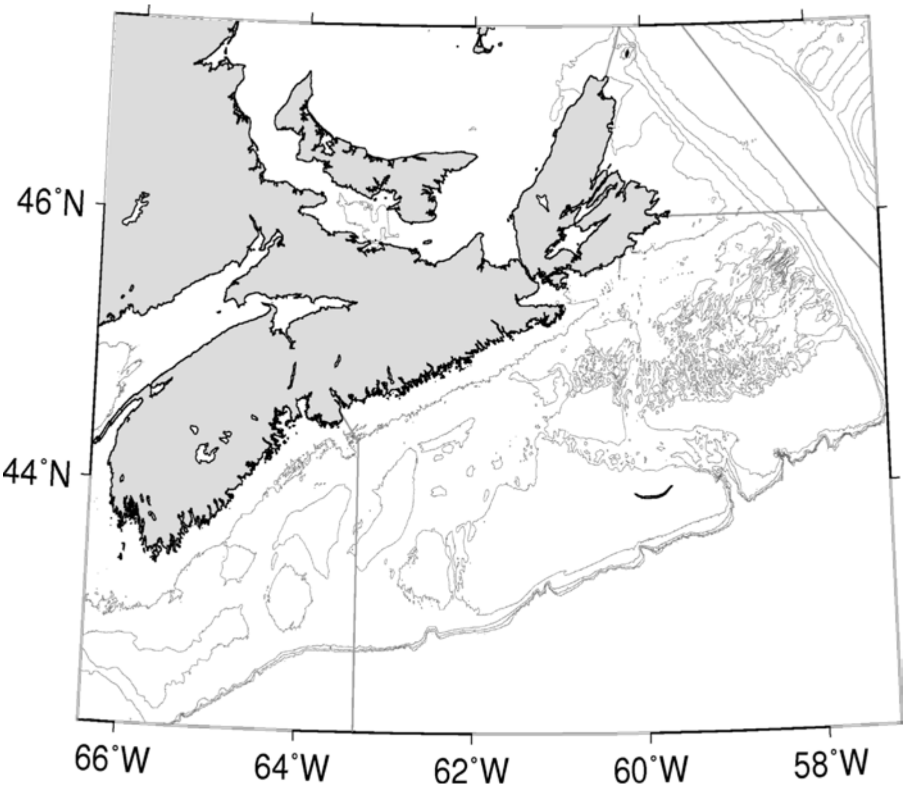

Figure 7.1.3. Snow crab fishing areas on the Scotian Shelf.

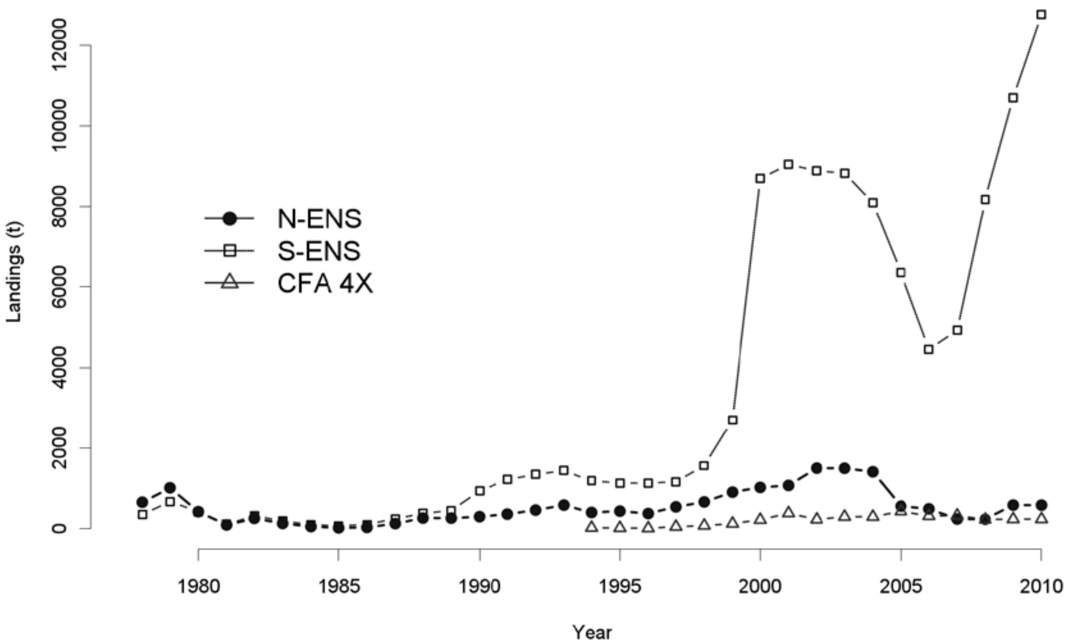

Figure 7.1.4. Historical landings of snow crab by fishing area between 1978 and 2010 from the Scotian Shelf.

General stock summary

- Landings in 2010 for N-ENS and S-ENS were 576 and 13 150 t, respectively, and they were 229 t in CFA 4X for the 2009/1010 season, representing increases of 0%, 22% and 0% relative to the previous year.
- Total allowable catches in 2010 were 576, 13 200 and 230 t in N-ENS, S-ENS and CFA 4X. In 2009, they were 576, 10 800, and 230 t.
- Non-standardised catch rates in 2010 were 55.0 kg/trap haul and 102.5 kg/trap haul in N- and S-ENS, and 36.0 kg/trap haul in 4X in 2009/2010 – representing a decrease of 27%, an increase of 14% and an increase of 27%, respectively, relative to the previous year.
- The shift towards earlier fishing seasons appears to have improved soft shell crab handling rates in both N- and S-ENS. In N-ENS, the soft-shelled crab discard declined from 6.6% in 2009 to 3.5% in 2010. In S-ENS, soft-shell handling decreased from 16% in 2009 to 7.7% of the Total allowable catch in 2010. Soft-shell discard rates in CFA 4X are very low.
- In N-ENS, the post-fishery fishable biomass of snow crab in 2010 was 2810 t (95% CI: 2180 to 3780 t; relative to 2790 t (95% CI: 2220 to 3840 t) in 2009. In S-ENS, the post-fishery fishable biomass of snow crab was estimated to be 48.5 $\times 10^3$ t (95% CI of: 32.2 to 77.9 $\times 10^3$ t) relative to 49.3 $\times 10^3$ t (95% CI of: 33.2 to 79.3 $\times 10^3$ t) in 2009. In CFA 4X, the pre-fishery fishable biomass was 930 t (with a 95% CI of 590 to 1440 t), relative to 1070 t (95% CI of 640 to 1730 t) in 2009/2010, representing a decrease of 13%.
- The leading edge of the main recruitment pulse of male crab detected in the mid-2000s first entered fishable sizes in 2007 and full entry to fishable sizes is expected in 2011/2012. Positive signs of adolescent crab suggest continued recruitment to the fishery for the next 2 to 3 years in N- and S-ENS. Recruitment beyond 2–3 years is potential due to the existence of animals in the 40–60mm size classes in S-ENS. These size classes are not observed in N-ENS. 4X currently shows a lack of adolescent crab recruiting to the fishery in next 3–4 years.
- Egg production remains above historic means though less than the peak observed in 2007/2008. Egg production is expected to begin to decline below historic means due to a lack of immature female crab between 30–60 mm, potentially affecting long-term recruitment patterns.
- High relative densities of predators of immature and soft-shelled snow crab were found in areas with high densities of immature snow crab. This adds uncertainty to the possible strength of future recruitment to the fishable biomass.
- Average bottom temperatures in 2010 were generally similar to those in 2009. The surface area of potential snow crab habitat was above the historical mean in all areas.
- By-catch levels, mostly of other crustacean species, are less than 0.014% of annual landings in ENS and approximately 0.17% in CFA 4X. By-catch has been extremely low in the historical record.
- Fishing mortality in N-ENS was estimated to be 0.19 (95% CI: 0.14, 0.24) or a harvest rate of 17.3%, unchanged relative to 2009. Good recruitment and significantly reduced soft-shell handling results in a positive outlook. Until a strong and persistent increase in fishable biomass is observed, long-term

harvest rates between 10% and 20% is part of the strategy for sustainability in this fishery. A decreased or status quo harvest strategy is recommended.

- Fishing mortality in S-ENS was estimated to be 0.23 (95% CI: 0.15, 0.33) or a harvest rate of 20.5%, a small increase relative to F=0.20 in 2009. Good recruitment suggests a positive outlook; however, the capture of soft shell crab remains an important issue for this fleet. Long-term harvest rates between 10% and 30% are part of the strategy for sustainability in this fishery. A decreased or status quo harvest strategy is recommended.
- Fishing mortality in CFA 4X for 2009/2010 was estimated to be 0.22 (95% CI: 0.15, 0.33) or a harvest rate of 19.7%, relative to F=0.19 in 2008/2009. Long-term harvest rates between 10% and 30% are part of the strategy for sustainability in this fishery. As recruitment into the 2011/2012 season is uncertain, a decreased or status quo harvest strategy is recommended.

Estuary and Northern Gulf of St. Lawrence (4S)

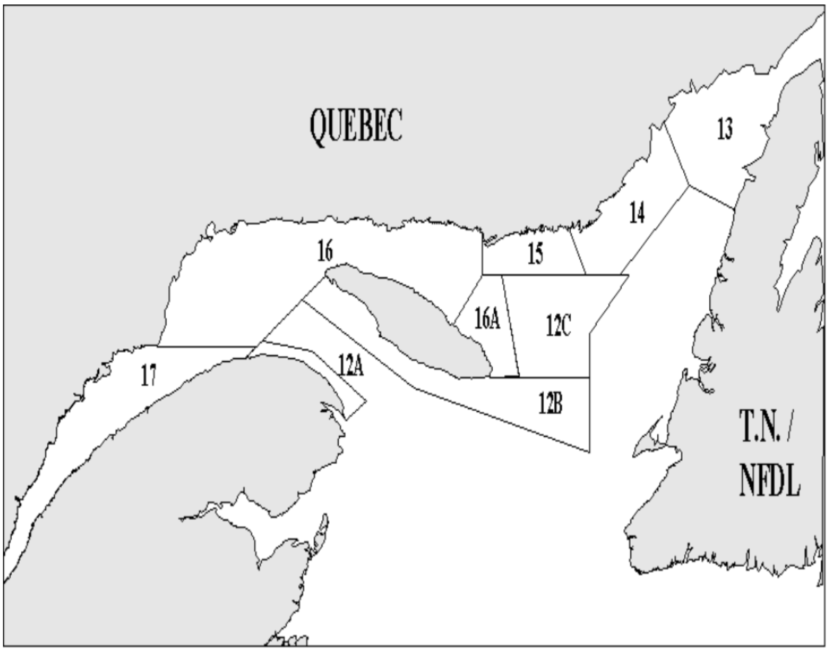

Figure 7.1.5. Snow crab fishing areas in the northern Gulf of St. Lawrence (Quebec Region).

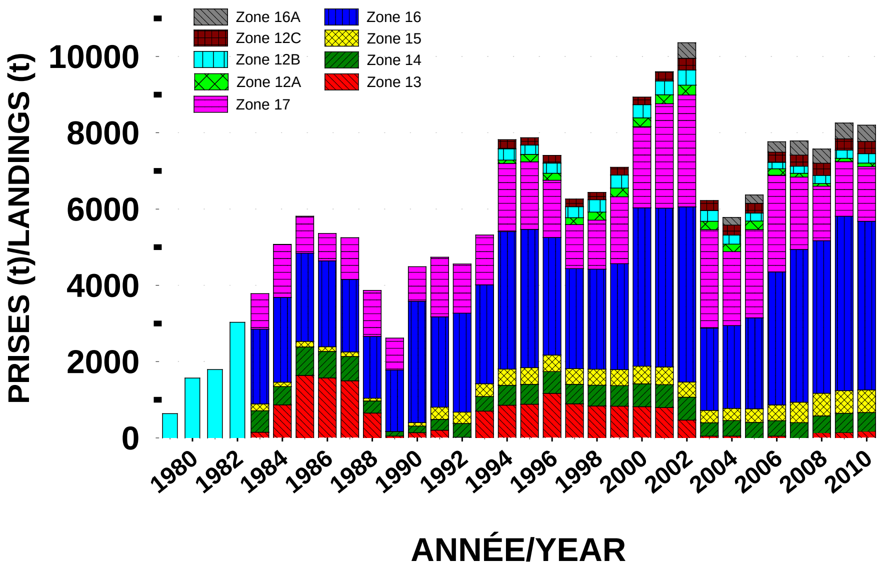

Figure 7.1.6. Historical landings of snow crab between 1980 and 2010 by fishing zone in the northern Gulf of St. Lawrence (Quebec Region).

General stock summary

Generally, in 2010, stocks in the Estuary and northern Gulf of St. Lawrence (areas 13-17, 12A, 12B, 12C and 12D) were characterized by a weak or decreasing trend in residual biomass. A high dependency on annual recruitment to the commercial biomass was observed in majority of fishing zones. In fishing zones 17 and 12A, decreased TAC level between 2006 and 2008 would have allowed the stock for stabilization and rebuilding of commercial biomass. In fishing zones 16 and 14, the decline of catch rates during the fishing season and post-season trap survey suggest a decreased biomass level. In fishing zone 15, commercial biomass level was relatively high based on the in-season catch performance, but the post-season survey results suggested contrarily. In 12C and 16A, decline of residual biomass may lead the commercial fishery to high dependency on new recruits. If maintenance or increase of the current biomass level is desirable an increase of exploitation is not recommended. In zone 13, commercial catch rate was at the mean CPUE between 1988 and 2009 and the predominance of crab with intermediate carapace conditions suggest a moderate level of fishing mortality in 2010.

In Area 17, an increase of TAC by 10% from 2010 would not result in a decrease of biomass index for 2011 if the level of recruitment in 2011 equals or superior to the 2009/2010. Fishing effort was estimated at 49 774 conical trap hauls (Cth) and 26 063 Japanese conical trap hauls (JCth).

In Area 16, a decrease of TAC by 15–25% would slow down commercial biomass level and avoid the total dependence on the annual recruitment to the fishery. Fishing effort was estimated at 101 078 Cth and 44 499 JCth.

In Area 15, TAC be maintained at the 2010 level or decrease of TAC by 10% should help maintaining the commercial biomass if selective exploitation on clean (younger) crab ceased and eastern part of the fishing zone is exploited. Fishing effort was estimated at 3381 Cth and 15 097 JCth.

In Area 14, a decrease of TAC by 20% from 2010 would help for stabilization of commercial biomass level. Fishing effort was estimated at 2881 Cth and 47 650 JCth.

In Area 13, the available information does not provide for any change to the pre-established management plan for the 2009 fishing season. Fishing effort was estimated at 298 Cth and 18 560 JCth.

In Area 12A, an increase of TAC by 20% from 2010 may not compromise the current increasing trend of biomass. Fishing effort was estimated at 4090 Cth.

In Area 12B, an increase of TAC by 10% would not result in a biomass decrease in the following season.Fishing effort was estimated at 5121 Cth.

In Area 12C, maintaining the current TAC level would help maintaining the biomass at acceptable level. Fishing effort was estimated at 1162 Cth and 17 133 JCth.

In Area 16A, maintaining TAC level set in 2010 should help keeping the acceptable biomass level. Fishing effort was estimated at 1220 Cth and 31 163 JCth.

Southern Gulf of St. Lawrence (4T)

Snow crab in management Areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.

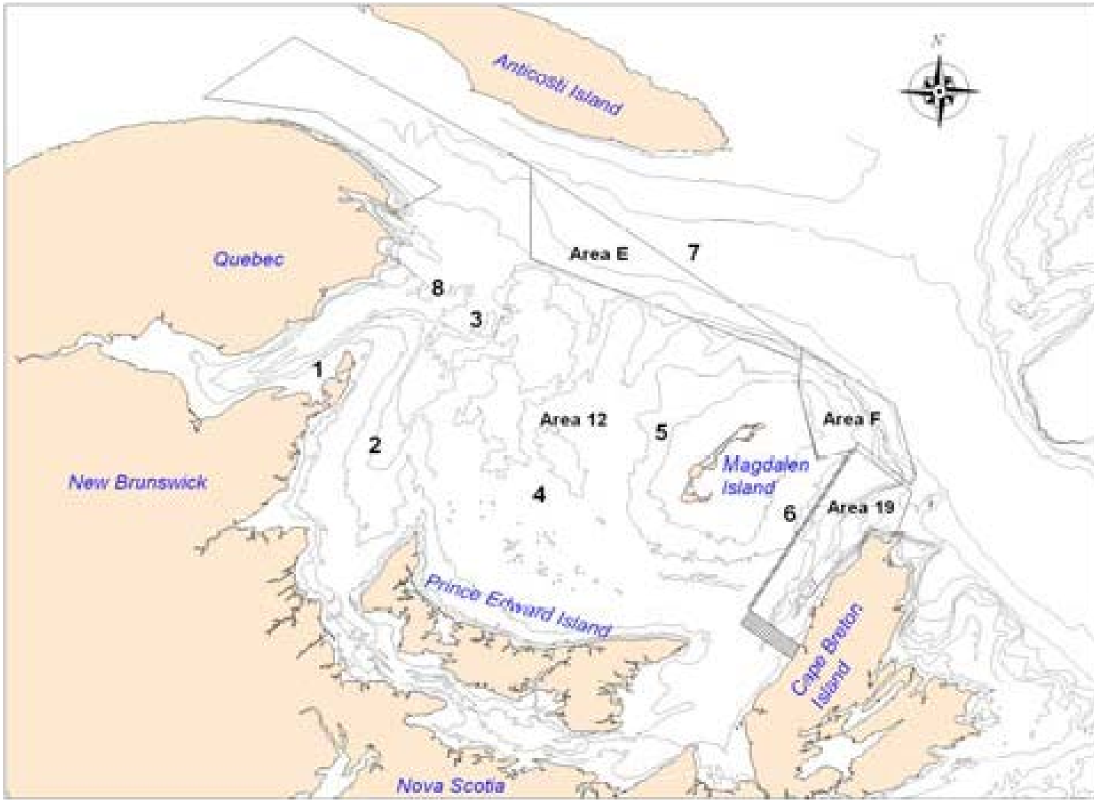

Figure 7.1.7. Snow crab fishing areas in the southern Gulf of St. Lawrence (Gulf Region).

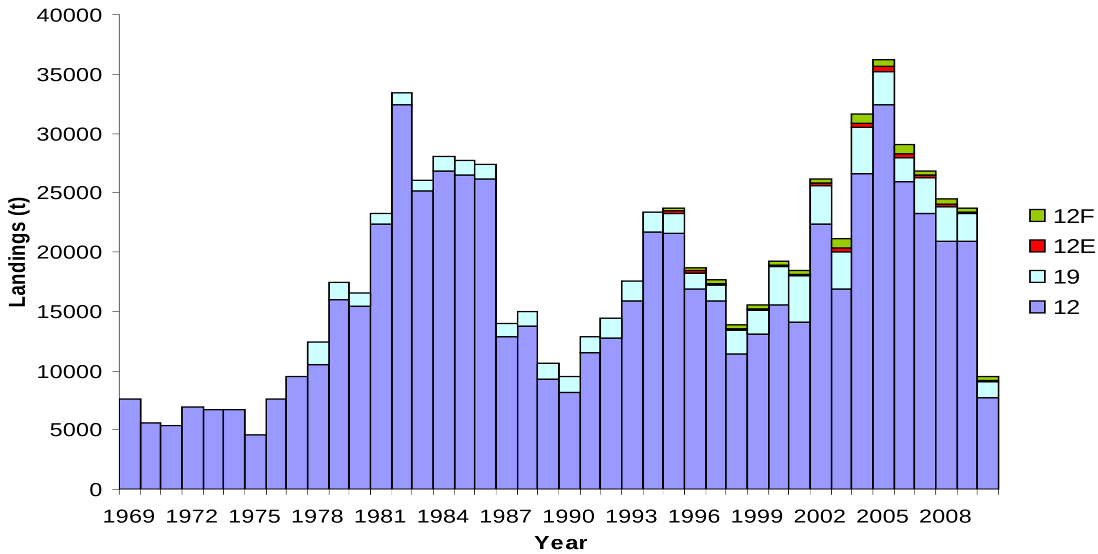

Figure 7.1.8. Historical landings of snow crab by fishing area between 1969 and 2010 from the southern Gulf of St. Lawrence.

Fishery

Area 12

The 2010 fishing season in Area 12 opened on April 21 and closed on July 18 with reported landings of 7719 t (quota of 7700 t) (Table 7.1.2, Figure 7.1.8). The fishing effort estimated from logbooks decreased from 508 053 to 370 762 trap hauls from 2005 to 2009 but decreased to 161 148 trap hauls in 2010. The CPUE is comparable to 2009 but decreased from 2007. The incidence of soft-shelled crab remained low at 6.5%, but locally, Chaleur Bay and 9 additional grids were closed during the fishing season.

Table 7.1.2. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	22 000	17 148	26 600	32 336	25 869	23 207	20 900	20 900	7700
Landings (t)	21 869	16 898	26 626	32 363	25 889	23 243	20 911	20 896	7719
CPUE (kg/trap-haul)	40.2	50.0	54.9	63.7	64.4	65.7	56.4	48.2	47.9
Effort (trap hauls)	544 454	337 960	484 991	508 053	402 702	353 775	370 762	433 527	161 148
Soft-shelled crab (%) in catches	4.6	3.3	3.0	3.9	3.1	2.0	3.0	5.0	6.5
Grids closed (total of 323)	100	0[1]	17	68	11	5	3	78	74

[1] In 2003, the area was divided into four sectors and none of the sectors were closed.

Area 19

- The 2010 landings in Area 19 were 1360 t (quota of 1360 t).
- The CPUE in 2010 increased compared to 2009 and represents the highest observed since the beginning of the fishery.
- The incidence of white-crab decreased from 13.2% in 2009 to 7.7% in 2010 and four of the nine sectors within Area 19 were closed during the fishing season.

The 2010 fishing season in Area 19 opened on 14 July and ended on 30 July with reported landings of 1360 t (quota of 1360 t).

In accordance with the white crab protocol, four of the nine sectors within Area 19 were closed during the 2010 fishing season due to high incidence of white crabs in the catches. The fishing effort in Area 19 decreased from 33 193 trap hauls in 2009 to 11 138 trap hauls in 2010.

Table 7.1.3. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 19.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	3285	3106	5092	2878	2000	3074	3002	2433	1360
Landings (t)	3279	3103	3894	2827	1989	3034	2929	2370	1360
CPUE (kg/trap-haul)	72.3	103.6	68.9	68.1	84.4	71.3	76.3	71.4	122.1
Effort (trap hauls)	43 662	29 952	56 517	41 512	23 566	42 553	38 388	33 193	11 138
White crab (%) in catches	3.5	3.7	7.1	9.8	8.3	8.3	10.2	13.2	7.7
Sectors closed	0/4	0/4	4/4	0/4	2/4	0/4	4/4	9/9	4/9

Area 12E

The fishing season in Area 12E began on May 5 and ended July 18 with reported landings of 50 t, 74.6% of the 67 t quota. The landings were 50 t, 74.6% of the 67 t quota. The CPUE in 2010 increased compared to 2009 but remained low. The incidence of soft-shelled crab in 2010 increased to 14.7%, compared to 7.8% in 2009. No grids were closed during the fishing season. The fishing effort in Area 12E decreased from 4653 trap hauls in 2009 to 1825 trap hauls in 2010.

Table 7.1.4. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12E.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	163	350	350	450	550	221	400	200	67
Landings (t)	165	345	349	449	411	220	187	67	50
CPUE (kg/trap-haul)	56.6	63.1	55.6	80.6	40.8	37.2	20.3	14.4	27.4
Effort (trap hauls)	2916	5471	6277	5571	10 074	5914	9232	4653	1825
Soft-shelled crab (%) in catches	0.3	1.2	1.5	2.9	7.8	1.3	10.1	7.8	14.7
Grids closed (total of 8)	0	0	0	0	2	0	0	2	0

Area 12F

In Area 12F, the fishery opened on April 12 and closed on July 17 with reported landings of 420 t (quota of 420 t).The fishing effort increased from 14 045 trap hauls in 2009 to 14 335 trap hauls in 2010. The CPUE in 2010 increased compared to 2009 but is among the lowest values since of the beginning of the fishery in 1995. The incidence of soft-shelled crab decreased from 11.4% in 2009 to 8.6% in 2010. Two of the three sectors within Area 12F were closed during the fishing season.

Table 7.1.5. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12F.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	378	808	808	480	815	408	585	465	420
Landings (t)	378	817	806	479	787	370	431	309	420
CPUE (kg/trap-haul)	85.2	78.1	74.8	93.7	55.9	30.2	27.8	22.0	29.3
Effort (trap hauls)	4437	10 460	10 775	5112	14 079	12 252	15 504	14 045	14 335
Soft-shelled crab (%) in catches	0.5	0.4	0.6	0.8	3.5	2.4	7.3	11.4	8.6
Sectors closed (total of 3)	0	0	0	0	0	1	3	3	2

General stock summary in the Southern Gulf

Statements of stock status are based on inferences from abundance data from annual trawl surveys conducted during July to September, over the entire area of snow crab distribution in the southern Gulf. This provides estimates of commercial biomass (hard-shelled adult males of legal size remaining after the fishery termed the residual biomass and soft-shelled adult males larger than 95 mm CW (R-1) that will be available to the fishery the following fishing season termed the recruitment) and future male recruitment to the fishery (prerecruits defined as R-4, R-3 and R-2). The prerecruits R-4, R-3 and R-2 represent adolescent male crabs with a carapace width range of 56–68, 69–83, and larger than 83 mm, respectively. A portion of these crabs could be available to the fishery in 4, 3 and 2 years, respectively. The abundances of small adolescent male and female instar VIII (34–44 mm CW) were also estimated as an indicator of long-term recruitment. It takes at least six years for an adolescent male of instar VIII to reach the commercial size of 95 mm CW.

Future and current spawning stock abundance consists of females (pubescent and mature). The term pubescent refers to females that will molt to maturity and mate the following year and become primiparous females (first brood). The term ‘multiparous’ refers to females which are carrying a brood for the second time or more. The term ‘mature females’, includes primiparous and multiparous females.

The biomass of commercial-sized adult males in the southern Gulf of Saint Lawrence from the 2010 trawl survey was estimated at 30 500 t with 95% confidence limits of 27 400 t to 33 700 t, the third lowest value since 1989. The estimated commercial biomass in the southern Gulf is comparable to 2009 (26 100 t; 95% CL 23 400 t – 29 000 t) but has decreased from 2004. The 2010 commercial biomass in Areas 12, 19, 12E and 12F correspond to 80.41%, 15.95%, 0.7% and 2.94%, respectively of the southern Gulf biomass estimate of 30 500 t.

The residual (carapace conditions 3 to 5) biomass of commercial sized male crab after the 2010 fishery was 13 500 t (95% CL 11 600 t – 15 700 t), an increase of 26% compared to 2009. The recruitment to the fishery at the time of the survey was 17 000 t (95% CL 14 900 t – 19 200 t) comprising 56% of the commercial biomass. The recruitment to the fishery is comparable to 2009 as expected from the 2009 assessment.

The exploitation rate in the southern Gulf of St. Lawrence in 2010, which is the ratio between the catch of the 2010 fishery and the commercial biomass estimated from the 2009 trawl survey, was 36.6%. Exploitation rates have followed a rising trend since the mid 1990s, a period for which rates around 15% were estimated (Figure 8). The total mortality, expressed as a proportion, was estimated at 48% in 2010 (Figure 8). This total mortality varied between 35% and 88% since 1991.

Newly introduced approach in the southern Gulf fishery since 2010

Within the Precautionary Approach (PA) framework (DFO 2009), the Limit Reference Point for biomass (B_{lim}) defines the critical / cautious zones and an Upper Stock Reference (B_{USR}) delimits the cautious / healthy zones on the stock status axis. A Removal Rate Limit Reference Point (F_{lim}) defines the maximum removal rate in the healthy zone. Reference points for the snow crab stock in the southern Gulf of St. Lawrence are: B_{lim} = 9400 t, B_{USR} = 34 000 t and F_{lim} = 40% (DFO 2010). The southern Gulf of St Lawrence commercial biomass estimate should be used for evaluating catch options relative to the defined reference points.

An increasing trend in recruitment of commercial-sized adult male crab to the fishery is anticipated until the 2015 fishery based on the 2010 survey abundances of adolescent males of R-2, R-3 and R-4. However, the abundance of male Instar VIII (future recruitment to the fishery in at least 6 years) observed from 2006 to 2009 is 42% lower than the peak observed in the previous recruitment wave from 1996 to 1999.

Since 2000, this fishery has become largely dependent on the annual recruitment (carapace condition 3) rather than on the residual biomass from one year to the next. The residual biomass since 2003 was maintained between 20 000 and 26 000 t, but declined to 10 700 t in 2009 and 13 500 t in 2010 (Figure 7.1.9).

The trajectory of stock abundance (biomass of commercial-sized adult male crab from the fall trawl survey in year t – 1) versus exploitation rate on this biomass in the fishery of year t is shown in Figure 7.1.9. Following an increase in biomass from 1990 to 1994, the biomass declined rapidly to low levels by 2000 and has varied between 26 100 t and 85 000 t during 2000 to 2010. Over the period of abundance, exploitation rates have varied between 36% and 50%, resulting in harvests of 18 500 to 36 100 t. The estimated biomass from the 2010 fall survey, which would be available to the fishery in 2011, was 30 500 t (95% CL range 27 400 t – 33 700 t). The 2010 biomass estimate is in the cautious zone of the PA framework. When the stock is in the cautious zone, the exploitation regime should be defined at a level to favour stock increase toward B_{USR}.

A risk analysis was developed based on the biomass estimated in the 2010 survey relative to various catch options in 2011 (Figure 7.1.9). The catch options and associated risk levels (probability of the event happening) are decisions to be made by management and stakeholders. For example, with a catch option of 11 000 t for the 2011 fishery, there is a 30% chance of exceeding the fishing rate limit reference point (F_{lim}) and a 21% chance of falling below the biomass limit reference point (B_{lim}) (Figure 7.1.9). Similarly, with a catch option of 11 000 t, there is a 24.5% chance of exceeding the biomass upper stock reference (B_{USR}). As an example, if 11 000 t is the catch option for the 2011 fishery in the southern Gulf, the TAC in each area will be distributed according to their respective proportions as follows: 8845.1 t in Area 12 (80.41%), 1754.5 t in Area 19 (15.95%), 77 t in Area 12E (0.7%) and 323.4 t in Area 12F (2.94%). Other indicators of stock performance could be examined using the same risk analysis structure.

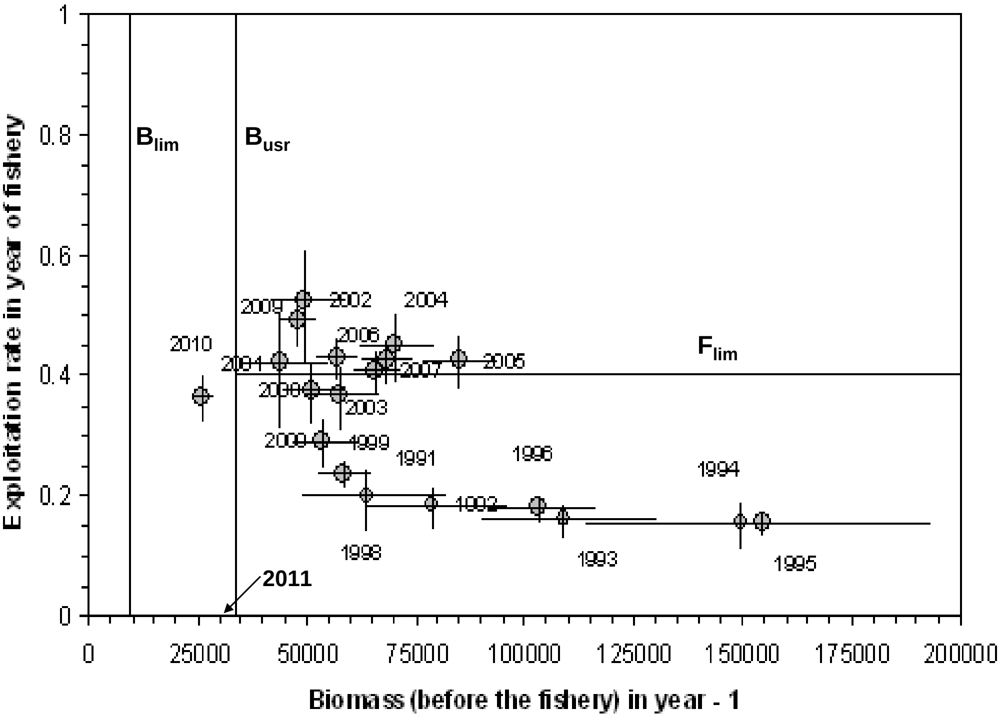

Figure 7.1.9. Trajectory of stock abundance (biomass of commercial-sized male crab as estimated from the trawl survey in year t-1) versus exploitation rate of this biomass in the fishery of year t. Year of the fishery is labelled on the figure. Error bars are 95% confidence interval ranges.

7.2 Greenland snow crab fishery

Provided by Greenland Institute of Natural Resources

Historical fishery background

Snow crabs are distributed along the West coast of Greenland and are commercially exploited primarily from Disko Bay in the North (up to 71° 30N) to Paamiut in the South (60° 45N). Commercial fishing for snow crab began primarily in inshore areas (within basis-line) in the mid-1990s and from 1999, also included offshore areas (outside basis-line).

Since 2004, the crab resource in Greenland has been managed in 6 areas (from North to South - Upernavik, Uummannaq-Disko Bay, Sisimiut, Maniitsoq-Kangaamiut, Nuuk-Paamiut and Narsaq-Qaqortoq, see Figure 7.2.1). The fishing fleet is made up of two components; small vessels (less than 75 GRT), which have exclusive rights for fishing inshore within the basis-line as well as offshore. Small vessels are, however, restricted to fishing in only 2 management areas during the year. Large vessels (greater than 75 GRT) may only fish in all offshore areas (outside the basis-line), but not within the “Crab Boxes”. Quota restrictions have been imposed to each of the 6 management area since 1995 and individual quotas to vessels larger > 75 GRT, but have only limited the catch in 2004. Management decisions allow increasing quota in each of the 6 management area, when the catch achieved the first fixed quota. Unused quota from larger vessels is re-allocated to the inshore fleet (small vessels < 75 GRT). Basically, there is now quota restriction for the small vessel.

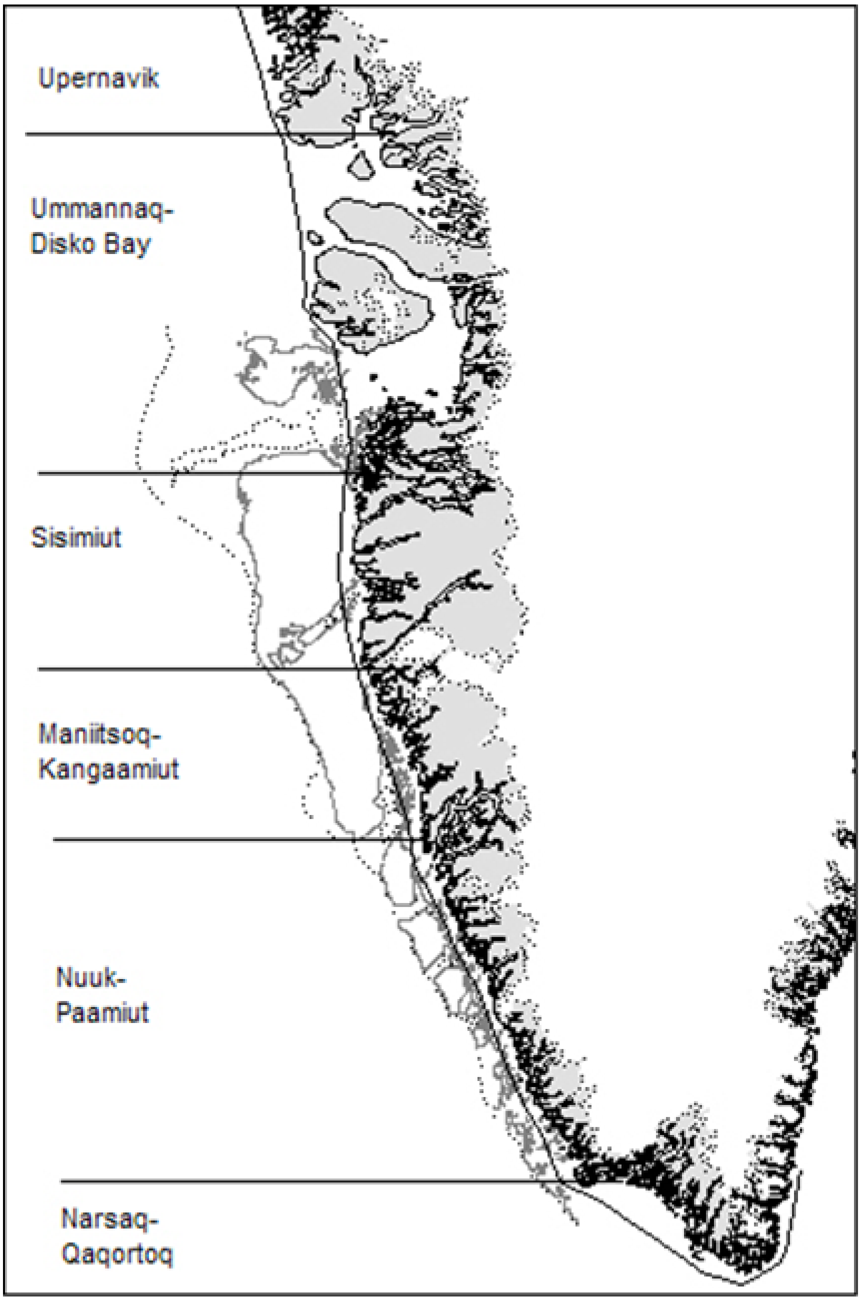

Figure 7.2.1. Management areas for snow crab in Greenland.

The fishery is regulated by prohibitions to land females and undersized males (<100 mm CW), logbooks for all vessels larger than 10 meters and closure of the fishery north of 64°N for 3 months (1 January to 31 March). There is also a regulation that states movement of the fishing effort when soft-shelled crabs exceed 20% of the catch, however the term "movement" is not specific and this is not monitored. From 2005 to 2007, the offshore crab fishery was closed in the management areas Maniitsoq-Kangaamiut and from 2005 to August 2007 in the offshore area of Sisimiut except for dispensation to 1 vessel that was allowed to fish in 2005. Only in 2006, the fishery was closed for 2½ months (1 July to 15 September) in all areas except Uumannaq-Disko Bay (closed only 1 month from 1 July to 3 August) to protect soft-shelled crabs.

The number of vessels with licenses to participate in the snow crab fishery increased by more than a factor of 3 from approx. 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. In 2008 the number of license holders amounted 74 in all management areas an 80% reduction compared to 2002. In 2009 the number of licenses increased to 117.

Greenland Institute of Natural Resources (GINR) provide stock assessment and total allowable catch (TAC) advice for the stock both inshore and offshore within each management area when sufficient data is available. The decision to give advice for both inshore and offshore areas was based on the assumption that snow crab migration is limited (tagging studies have indicated approx. 10 km per year) and therefore the resource in different areas is considered to be spatially independent.

Catch and effort

The historical development of catch, effort and CPUE within each management site of the crab fishery in Greenland is shown in Table 7.2.1, Figure 7.2.1. Landings increased from approx. 1000 tonnes in 1995 to a peak of approx. 15 000 tonnes (Quota 26 800 tonnes) in 2001 (based on landings from small vessels and catch from logbook data from large vessels >75 GRT). From 2001 to 2007 total catch decreased by approx. 89% to 2189 tonnes (Quota 4380 tonnes). Landings increase to 3191 tonnes (Quota 4680 tonnes) in 2009 and preliminary data indicate an additional decrease in landings in 2010 (approx. 1.800 tonnes ultimo October 2010, Quota 4050 tonnes) (Table 7.1.2).

In 2008 and 2009 quota was increased from 500 tonnes to 800 tonnes in the management area Sisimiut and from 700 tonnes to 1000 tonnes in Nuuk - Paamiut management area (only in 2009). The increasing quota was based on re-allocation (removing a part of the quota from five vessels > 75 GRT) allowing small vessel < 75 GRT to increase catches inshore as well as offshore.

The distribution of landings and geographic distribution of the fishery in each management area in Figure 7.2.1 show that most of the landings in 2008 have predominately come from management Sisimiut (42%), whereas Disko Bay–Uummanaq and Nuuk-Paamiut amounted 27% and 26% respectively of the total landings.

The total fishing effort (trap hauls) has declined by 91% since 2001 (from 3416 to 323 thousand trap hauls during 2001–2008). The decline has been mostly due to a declining number of participants in the fishery. Preliminary and incomplete logbook data for 2010 shows total effort is 220 thousand trap hauls.

Research Surveys

Since 1997, trap surveys have been conducted annually in inshore areas of Disko Bay and Sisimiut. In 2000, a Sisimiut offshore area (Holsteinsborg Dyb) was included in the Sisimiut trap survey. In 2002, annual offshore trap surveys were initiated in areas between Nuuk and Paamiut and in 2003 were extended north to include the offshore in the Maniitsoq-Kangaamiut management area.

Methods

Snow crabs are sampled with Japanese-style conical traps with large (70 mm) and small (21 mm) mesh sizes. Sampling stations are at predetermined fixed positions for all years and soak times range between 14–24 hrs depending on weather conditions. Bottom temperatures are recorded at each station.

For males, the carapace width (CW) and chela height (CH) are measured (± 0.01 mm) to determine size and molt status (adolescent or adult). Male snow crabs stop growing after their terminal moult. Sexually mature males are referred to as adolescents (recognized by their small claws) prior to the terminal molt and as adults after their terminal molt (large claws). Males reach legal size (≥100 mm CW) at about 9 years of age. The range of carapace widths defining the adolescent male groups which are presumably 1, 2 and 3 years from recruitment to legal size are: ADO^{-1}, 82.2–100mm CW; ADO^{-2}, 67.3–82.2mm CW and ADO^{-3}, 53.2–67.3mm CW.

For females, the CW and abdomen width (AW) are measured (± 0.01mm) to determine size and maturity. Females that have mated once and are carrying their first clutch of eggs are called primiparous, while females that are carrying their second clutch and have mated more than once are called multiparous. They are distinguishable by the number of scars on their legs caused by mating and by shell conditions. Shell condition in both males and females is determined on a scale of 1–5 according to guidelines by Sainte-Marie (1993).

Data from trap survey catches of males are used to determine CPUE (kg/trap), mean CW of legal-size males, shell condition and NPUE (number/trap) of adolescent males to assess recruitment prospects. Male and females size distributions are also described to follow the progression of size modes through the populations and determine primiparous/ multiparous ratios within the female population.

Inshore surveys in Disko Bay and Sisimiut

In Disko Bay, 43 stations are sampled annually and in Sisimiut, 40 stations are sampled, from May to June. The sampling gear consists of a longline of 10 large-mesh (70mm) and 2 small-mesh (21mm) conical traps fished at depths ranging from 100–600m. Traps are placed approx. 40 m apart and baited with squid.

Offshore surveys in Sisimiut, Maniitsoq and Nuuk-Paamiut

Fifteen stations are sampled annually in Sisimiut offshore in June and a total of 30–60 stations are sampled in the Nuuk-Paamiut and Maniitsoq offshore areas in August/ September. The sampling method in Sisimiut offshore is the same as the method used inshore in Disko Bay and Sisimiut. In 2002, the sampling in the Nuuk-Paamiut offshore survey was also the same as the method inshore. In 2003, however, the offshore sampling method used in Nuuk-Paamiut and Maniitsoq was changed such that each station was then sampled using a long line of 16 traps, eight large-meshed traps alternating with eight small-meshed traps at approx. 40 m apart and baited with squid.

Input data from commercial fishery to assessment

No sampling from the commercial fishery has been conducted since the fishery began in 1996.

Available logbook and landing statistics is used in data analysis from the commercial fishery. Logbooks nominal catches has since 2003 covered more than 85% of the total landings in Greenland. Before 2003 less than 20% of the fishing fleet were using logbooks.

In order to calculate a standardised CPUE index, a GLM analysis (multiadditive model) was carried out using haul by haul logbook information including zero catches. The model includes year, month and vessel effects. For more information see Burmeister (2010).

Biological information of 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 very unique about this study is the possibility of investigating life history traits of an unexploited population of snow crab, something non-existent elsewhere in the world. There are 4 components to this study. The effects of temperature and exploitation on snow crab population dynamics and – especially – on reproductive potential are multifaceted, complex and possibly synergistic.

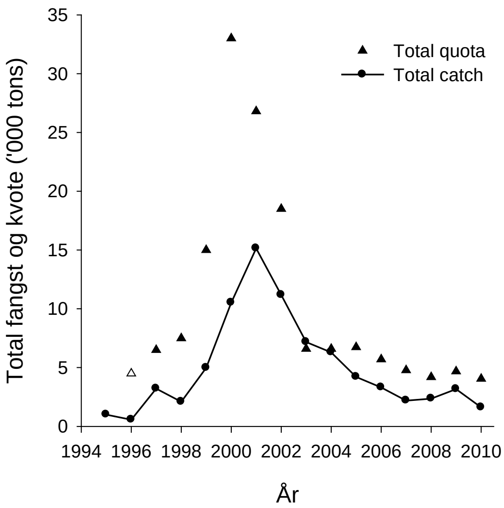

Figure 7.2.2. Total catch and quota in Greenland from 1995–2010. Data from 2010 is only preliminary and incomplete.

Table 7.2.1. Catches, catch rates (CPUE) and effort in management inshore and offshore areas from 2000–2010. *2010 data is preliminary and incomplete.

Management Area	Year	Total catch (tons)	Quota	Number of issued permits	Number of active vessels	Inshore catch (tons)	Inshore CPUE (kg/trap)	Inshore effort ('000)	Offshore catch (tons)	Offshore CPUE (kg/trap)	Offshore effort ('000)
	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
Uummannaq-Diskobugt	2002	3,319	--	--	--	2,970	3.3	900	349	3.0	116
	2003	2,739	--	--	50	2,482	3.7	679	257	2.6	97
	2004	2,341	--	--	40	2,174	3.4	632	167	3.7	45
	2005	1,500	1718	43	31	1,404	3.9	363	96	4.0	24
	2006	1,134	1600	43	21	1,008	4.6	221	126	6.7	19
	2007	698	1530	39	17	574	4.2	138	123	5.1	24
	2008	627	1400	25	8	531	5.0	107	96	5.2	19
	2009	657	700	22	12	471	5.1	93	186	5.5	34
	2010*	217	600	19	5	192	5.8	33	25	5.3	5
	2000	2,534	--	--	--	491	2.8	175	2,043	6.4	319
	2001	2,602	--	--	--	327	2.9	113	2,275	4.6	495
Sisimiut	2002	2,724	--	--	--	473	4.6	103	2,251	3.5	643
	2003	1,633	--	--	34	692	3.7	187	941	3.1	304
	2004	1,432	--	--	19	1,111	3.9	286	321	4.9	65
	2005	1,125	900	12	13	891	6.5	137	234	6.4	37
	2006	736	750	12	10	725	8.3	87	11	11.1	1
	2007	784	850	9	12	559	7.4	75	225	12.8	18
	2008	979	700+300	11	12	765	8.8	87	214	13.1	16
	2009	951	500+300	21	20	597	8.4	71	354	7.6	47
	2010*	470	800	19	16	220	8.6	26	250	8.3	30
	2000	944	--	--	--	563	4.3	131	381	7.6	50
	2001	1,835	--	--	--	1009	3.7	273	826	5.0	165
Maniitsoq-Kangaamiut	2002	1,775	--	--	--	1032	3.8	272	743	2.7	275
	2003	485	--	--	12	40	3.5	12	445	2.8	160
	2004	116	--	--	9	78	2.4	33	38	2.1	18
	2005	73	200 (inshore	12	6	62	4.2	15	11	3.6	3
	2006	72	100(inshore)	16	6	61	4.3	14	11	4.3	3
	2007	187	300	11	4	13	2.9	5	174	10.2	17
	2008	130	300	13	8	19	5.9	3	111	9.0	12
	2009	259	250	21	11	88	6.2	14	171	5.9	29
	2010*	140	300	18	2	140	7.3	19	--	--	--
	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
Nuuk-Paamiut	2002	2,531	--	--	--	1,770	2.8	632	761	2.8	272
	2003	2,315	--	--	26	704	3.4	207	1,611	4.2	385
	2004	1,795	--	--	22	180	4.5	40	1,615	8.0	203
	2005	2,295	--	26	22	262	8.0	33	2,033	6.7	302
	2006	1,173	1,800	24	18	204	7.3	28	969	3.0	328
	2007	521	1,600	25	10	111	7.2	15	410	7.4	56
	2008	617	1,600	24	6	200	7.2	28	418	9.1	46
	2009	1,111	700+300	31	13	435	7.5	58	676	7.6	89
	2010*	519	1,000	22	9	141	7.7	18	378	7.1	53
	2000	2	--	--	--	0	--	--	2	--	--
	2001	822	--	--	--	822	--	--	0	--	--
Narsaq-Qaqortoq	2002	643	--	--	--	642	--	--	1	--	--
	2003	133	--	--	11	123	--	--	10	--	--
	2004	541	--	--	10	32	3.9	8	2	1.0	2
	2005	76	--	7	6	76	8.3	9	--	--	--
	2006	0	--	3	--	--	--	--	--	--	--
	2007	0	--	4	--	--	--	--	--	--	--
	2008	--	--	--	--	--	--	--	--	--	--
	2009	187	?	12	5	187	9.2	20	--	--	--
	2010*	273	300+150	15	6	266	7.9	34	9	8.7	1

7.3 Saint Pierre et Miquelon snow crab fishery

The French fishery on the Snow crab is really low in comparison with the Canadian one. In effect, the French fishery is represented by 8 boats from the Saint Pierre et Miquelon Island on the south west coast of the Newfoundland. The fishing area is a close corridor in the 3PS area. The fishing season starts the first April until the landings reach the quotas. In reality, during the last 9 years, the vessels stopped when the abundance became too law. In 2010, the landings were the highest of the 2002–2010 time-series (Figure 7.3.1). Before during a 5 years period (1997 and 2001), the landings were very high in relation to a high abundance and the development of the fishery.

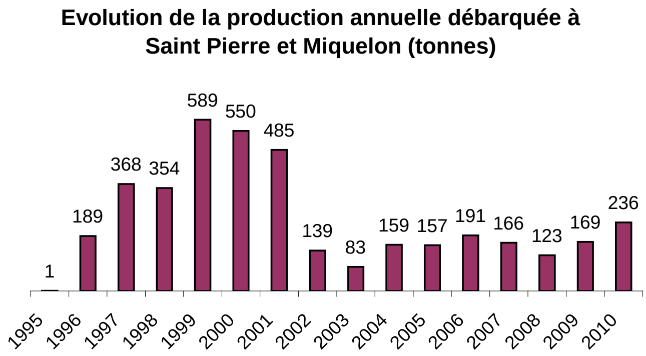

Figure 7.3.1. Landings of snow crab (*Chionoecetes opilio*) at Saint Pierre et Michelon in the period 1995–2010.

In 2010, the increase of the landings is really important. This situation is explained by an increase of the abundance of the Snow crab. Indeed, the fishing effort (number of pots) is the same in 2009 and 2010. The abundance index increase around 30% in 2010. This situation is confirmed by the status of the stock in the Canadian water. The other index as the recruitment has a similar evolution suggesting a good status of the stock for the 2 following seasons. All the regulation in the Canadian has a positive impact on the stock. However, the influence of the environment conditions seems to greatly influence the mortality of the first stage of the snow crab and the future available biomass for the fishermen.

7.4 Snow crab in the Barents Sea

Provided by the IMR

The snow crab was recorded in the Barents Sea by Russian scientist for the first time in 1996 (See Kuzmin 2000). Since then the abundance of crabs has increased almost exponentially, particularly in the Russian part. There is no record on how this crab was introduced to this area, and the most prominent hypothesis is that it has migrated north of Siberia from the Beaufort Sea. The crab has established a self reproducing population in this area and in 2011 Russian scientist estimate the stock of males with a carapace with larger than 95 mm, to be between 20 and 40 million specimens (Bakanev pers comm.). So far, only a few specimens have been recorded in the Norwegian part of the Barents Sea, but the abundance is expected to increase and will probably distribute more northerly than the already established red king crab (See figure 7.4.1).

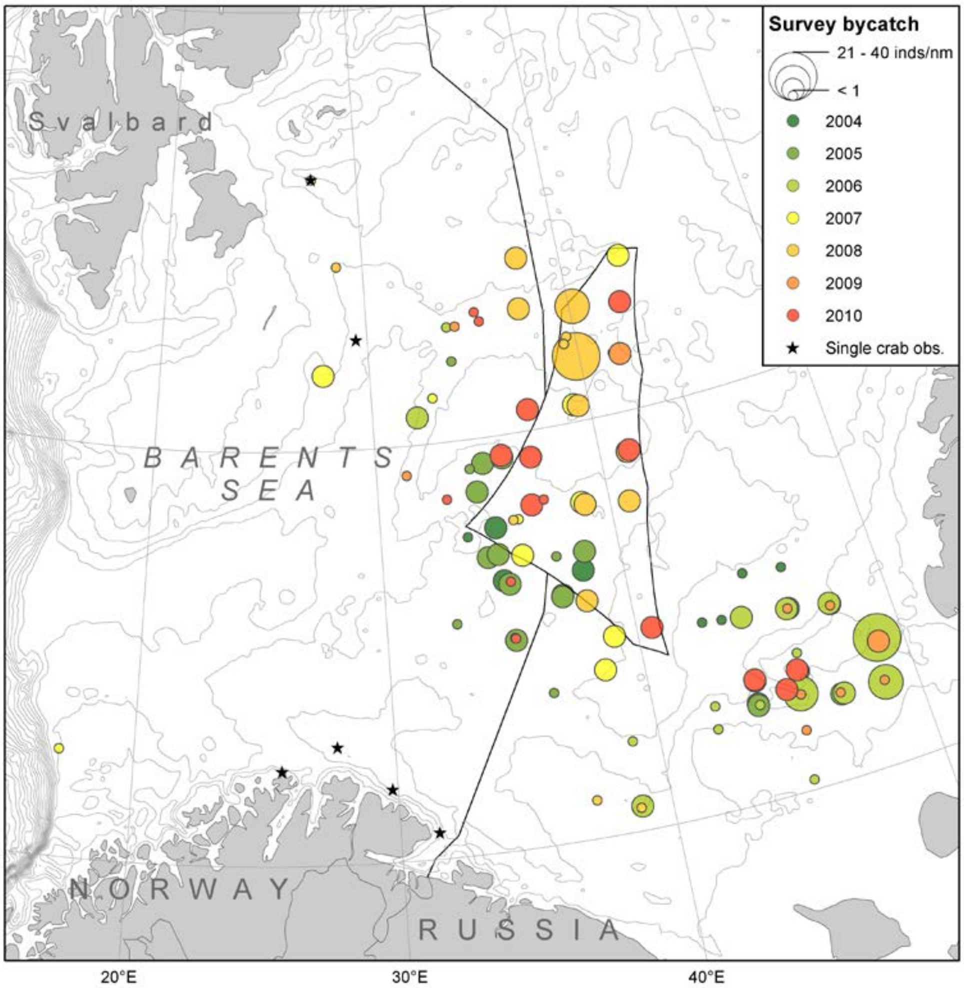

Figure 7.4.1. Bycatches of snow crab by Norwegian vessels in the Barents Sea during 2004–2010.

8 Velvet crab (*Necora puber*)

8.1 Velvet crab fishery in Shetland

The velvet crab (*Necora puber*) fishery has been rapidly increasing in its importance to Shetland's inshore fleet, and landings have almost tripled since the Regulating Order was introduced in 2000 (Figure 8.1.1). In July 2001 the Shetland Shellfish Management Organisation introduced a 70 mm carapace width minimum landing size (the national MLS is 65 mm), and also implement summer closed seasons to protect the stocks during the main moulting period. In recent years these have been rolling closures with all fishermen required to stop fishing for a predetermined period in the summer months. Fishermen choose their tie up period to coincide with the moult in the area they fish. This method allows for the spatially variable nature of the moult (Leslie & Shelmerdine 2008).

Landings of velvet crabs have shown a pattern of increase since logbook data collection began in 2000 with a peak at over 270 tonnes in 2009. Effort has been somewhat variable with an initial period of decrease followed by rapidly increasing numbers of creels fished between 2005 and 2009/2010. This resulted in an increasing trend in LPUE between 2000 and 2007 where it reached a high of 0.68kg per creel. This has been followed by a marked decrease in LPUE to 2010 with values falling to 0.47 kg per creel, though LPUE remains higher than during 2000–2005 (Figure 8.1.1).

A generalised additive model was used to further examine trends in LPUE. All four of the explanatory variables, had a significant effect on the model and were therefore retained in the analysis (Figure 4). LPUE showed an increasing trend over the initial period of data collection with a marked increase between 2005 and 2008, this was followed by decline to 2010. Seasonal data indicated declining LPUE from January to April with an increasing trend observed until September, then stabilising towards December (note that the data include landings in 2000 and 2001, before the closed period during the summer months was implemented in this fishery) (Figure 8.1.2).

Variability was observed both between vessels and for individual vessels. The variability of LPUE within areas appeared to be less than for shown for vessels (Figure 8.1.2). LPUE also appeared to be higher in areas to the north of the Shetland.

Table 8.1.1. Data for the Shetland velvet crab fishery; landings (Tonnes), effort (no. of creels lifted), and LPUE (kg/creel).

Velvet Crabs	Landings (Tonnes)	Effort (no. creels lifted)	LPUE
2000	71.71	259156	0.29
2001	89.64	226589	0.35
2002	32.79	75023	0.43
2003	102.49	223877	0.46
2004	62.14	160529	0.35
2005	68.03	162655	0.41
2006	97.02	199816	0.47
2007	159.20	234562	0.68
2008	218.03	352411	0.64
2009	270.50	497952	0.57
2010	221.89	482587	0.47

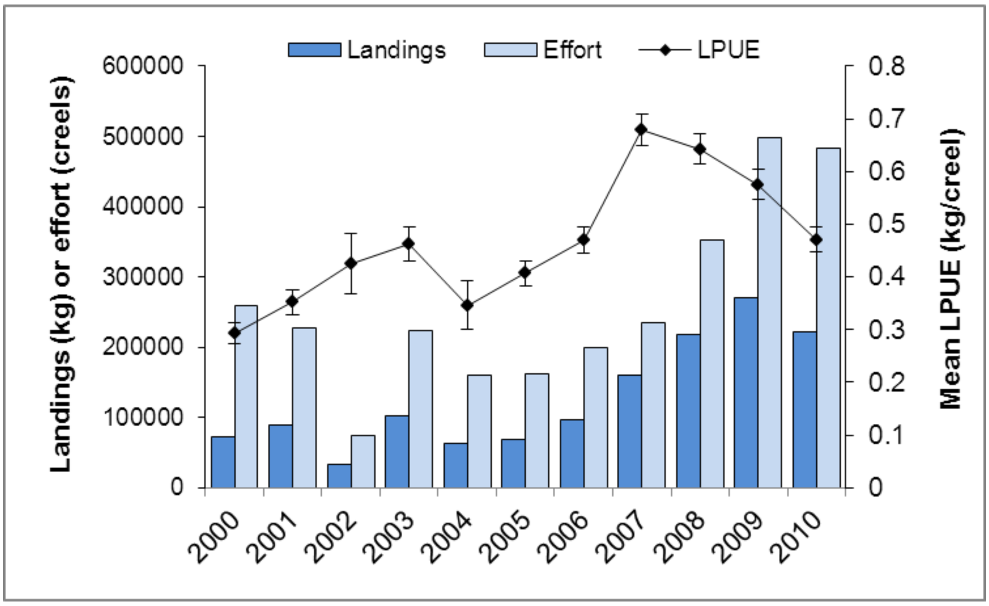

Figure 8.1.1. Total velvet crab landings (kg), total numbers of creels catching velvet crabs, and the average LPUE obtained from SSMO logbook data with 95% confidence intervals shown.

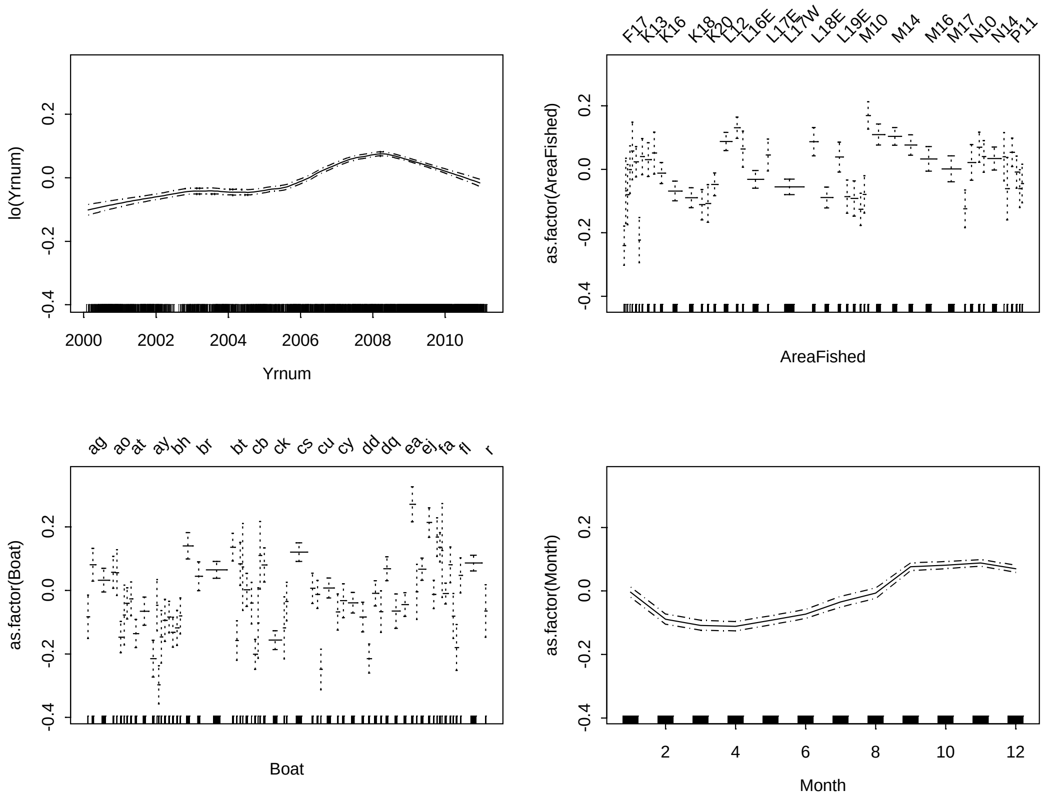

Figure 8.1.2. Velvet crab diagnostic GAM plots of the fitted curve (continuous line) and factors included in the minimal model. Data are: Yrnum. – a monthly time-series from Jan 2000 to Dec 2010; Month - month of fishing regardless of year, months are represented by numbers commencing with 1 = January; 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.

9 Spider crab (Maja brachdactyla)

9.1 Spider crab fishery in England and Wales

The main fishery for Spider crabs is with pots, but some are caught with nets. There is a minimum legal size for catch, and berried crabs and soft shell crabs are not allowed to catch. Escape gaps are obligatory in pots in some areas.

Table 9.1.1. Landings of spider crab (*Maja brachdactyla*) in France.

Year	Landing (kg)
2002	3623
2003	3698
2004	3888
2005	3750
2006	4294
2007	4303
2008	4010
2009	3900
2010	3600

Table 9.1.2. Landings of spider crab (*Maja brachdactyla*) in England and Wales 2000–2010.

Year	Landing (tonnes)
2000	1005
2001	1183
2002	1169
2003	997
2004	608
2005	488
2006	1554
2007	1447
2008	1003
2009	838
2010	773

Table 9.1.3. Management measures for spider crab (*Maja brachdactyla*) in England and Wales.

Species	Maja brachydactyla	
	Stock	All
Management measure		E&W
Licensing		Yes
Limited Entry		<10m
Closed seasons		No
Days at sea		>15m in Celtic Sea
Closed areas		No
Others		
Minimum size		120mm CL females; 130mm for males
Maximum size		No
Berried female legislation		No
Soft crabs		No
Single sex fishery		No
Others		
Vessel size		Regional
Vessel power		No
VMS		>15m
Log book returns		Yes
Others		
Trap limits		Regional
Trap size		No
Escape vents		Regional and gear specific
Biodegradable panels		No
Others		No
Marked gear		Regional

Table 9.1.4. Stock summary for spider crab fishery in England and Wales.

	England
Number of stocks in which national fleet is active	None currently defined but fisheries in eastern English Channel, western English Channel, Celtic Sea and southern Irish Sea
Stock areas (cross reference to map)	
Indicator	
Landings	1983–2010
Effort	Targetted potting and netting effort not available
LPUE	No
DPUE	No

Size frequency data	Yes. At least recent i.e. 2004–2010 maybe much longer series
Others	No
Analytical assessment methods	
LCA	No
Production	No
Change in ratio	No
Depletion methods	No
Others	No
Data sources	
Surveys	
Larval	No
Juvenile index /biomass	Possibly
Adult index/biomass	
Non target surveys	
Commercial	
Observer/self reporting/reference fleet	No
Size frequency data	Yes
Logbooks	No
Tag returns	No
VMS	No
Electronic logbooks	No
Others	No
Biological parameters	
M	
Growth data	
Fecundity	
Size at maturity	
Others	
Analytical assessment outputs	
Biomass	No
Spawning stock	No
Recruitment	No
Fishing mortality	No
Yield per recruit	No

9.2 Spider crab fishery in France

The French spider crab fishery is large. All along the coast from Boulogne to Arcachon, boats catch spider crab. The main "métier" targeting it are the net crustacean in North Brittany and potters in Brittany and Normandy. The net crustacean fleet is located in the North Brittany, mainly around the Bay of Saint Brieuc and Granville. The number of boat in this fleet is around 65. Their activity is at maximum between the middle of October until the end of March. This fleet catch more than the half of the landings. From the logbook data of this fleet, it is really difficult to develop an abundance index. Indeed, the net fishing time is very irregular from 2 or 3 days until 15 days. Moreover, in function of the fullness of the crab, the discard evolves a lot during the season. We are starting to work with a selection of boat to get more precise data in order to propose an abundance index.

A other part of the landing is caught by potters. These potters catch spider crab during spring when the spider crab move towards the coast. Among these potters, a large part target lobsters and spider crab is a little considered as bycatch. The number of boat of this potter fleet is around 400 and the majority from Brittany and Normandy.

All these boat (netters and potters) have a licence to target spider crab. Inversely, the trawlers cannot have a licence and the catch of spider crab cannot exceed 10% of the total catches. Regularly, some trawlers try to get the crustacean licence because their spider crab catch in their fishing areas can be higher than the 10%.

The official landings are around 4000 tons, but the real landings are more closed to 6000 tons. Indeed, a part caught by little potters are directly sold by fishermen without any declaration in auction and one part of the trawler landings are not declared because they exceed the 10%.

10 Working Group discussions on ToRs b) - f)

10.1 Term of Reference b)

Catch or landings per effort data are available for both the *Cancer pagurus* and the spider crab (*Maja brachdactyla*). The Working Group members discussed the utility of these data for stock assessment purposes and concluded that because of the varying quality of the data, until more reliable data can be obtained their use for stock management purposes is not advised. The WG does not recommend application of biological reference points for management purposes for stocks relying solely on catch or landings statistics. Unless consistent and reliable catch and effort data are available application of biological reference points should be limited to fishery independent data such as the annual surveys on snow crabs in Canada and Greenland, and on the red king crab in Norway.

The Working Group agreed to highlight biological reference points as an issue at the next meeting by inviting someone with greater expertise in the field to attend.

10.2 Term of Reference c)

There were no data presented on estimates of natural mortality of crabs.

Investigations of the red king crab (*Paralithodes camtschaticus*) stock in northern Norway described historical changes in fecundity and sex ratios, revealing a decline in individual fecundity and the incidence of large females since 2000 (see Annex 4). A possible explanation for the disappearance of large females could be the removal of large males by the male only fishery. However, the reasons for the decline in fecundity might be more complex and the analysis was complicated by the introduction of a quota for large females in 2008 (Annex 4).

One presentation described how along the western coast of Greenland the size (CW) at terminal moult of both male and female snow crabs (*Chionoecetes opilio*) was positively correlated with the mean bottom temperature. Individuals at warmer sites were smaller at instar stages compared with crabs from colder sites, had a greater number of instars before terminal moult, and matured at a larger mean size than crabs from cold sites. Other than fishery related effects (primarily the selective removal of large males), factors such as length of season, salinity and diet were not considered to impact on this phenomenon.

Similar observations were made from the snow crab fisheries in the southern Gulf of St. Lawrence in Canada and a report was presented on the implications of factors such as moult-skipping, delayed maturity and larger size at age (especially in male crabs) for fisheries issues such as yield-per-recruit (MM ref?).

Interim results from a large scale tagging study of the *Cancer pagurus* in the English Channel were presented. Since the last major study, some 40 years ago, there has been a major expansion of the crab fishery in the area, probably due to climate change. The project was designed to look for possible changes in the distribution and behaviour of the edible crabs and to provide more information on the structure of the crab stock in the area. Both conventional T-bar tags and Cefas G% electronic data storage tags were deployed. Results showed there has been no change in the pattern of movements of edible crabs and that spawning females moved west, spawned and incubated their eggs and then continued to move west, with no evidence for movements back to their original areas. Rates of movement and residency were modelled using the basic population equation of Hilborn (1990) along with modifications suggested by Aires da Silva *et al.* (2005), for including terms for tag loss and natural mortality (Annex 6).

10.3 Term of Reference d)

A study of the impact of the introduced red king crab on soft bottom benthos in Varangerfjord, Norway was presented. Varangerfjord was invaded by the red king crab some 30 years ago and is the area of Norwegian waters where the crab has been present longest. A comparison of the diversity and biomass of benthic species at several locations in the fjord, before (1994) and after (2008) the crab became abundant, revealed significant changes. After the arrival of *Paralithodes camtschaticus* in the area, large specimens of several species of bivalves, echinoderms, polychaetes and others were totally absent in the samples. In addition, the average biomass of both in- and epifauna had decreased from year 2006 to year 2010. Sediment profile images (SPI) indicated serious effects of the removal of large infaunal animals such as polychaetes and bivalves. These animals are thought to secure oxygenation downwards in the sediment, and when absent, the anoxic layer was much closer to the surface. This situation may reduce mineralization processes in the system.

10.4 Term of Reference e)

The WG agreed not to discuss ToR e), diseases in crabs, due to lack of competence in this field among the participants present at the meeting. The group also suggested the existing ToR e) to be deleted from the list of ToRs in 2012 since there is another ICES Working Group dedicated to this issue (WGPDMO). In situations where diseases in crabs will be an aspect in the Group's topics or discussions, this could easily be included in ToR c) dealing with biological information required for assessment.

10.5 ToR f – The Working Groups contribution to the ICES Science Plan

The Working Group members used the last part of the meeting to discuss the contribution of the WG to the ICES Science Plan. The points below indicate how the WG thinks it can contribute.

- Climate change processes and prediction of impacts

A modelled scenario of effects of temperature increases for the spatial distribution and survival of the snow crab in Canadian waters reveal serious consequences for the crab stock. Slight increases in temperatures close to the bottom will limit the spatial distribution as well as affect the population biology (size at maturity, growth etc.).

The temperature in the coastal waters of Norway has increased steadily over the last 10–20 years, possibly allowing a dispersal of the edible crab northwards to new areas. This increase in northwards distribution will be monitored.

- The role of coastal-zone habitat in population dynamics of commercially exploited species

Many commercially exploited crab stocks belong to the coastal-zone ecosystems, and these habitats are therefore extremely important for these stocks.

- Impacts of fishing on marine ecosystems

Most crab fisheries are carried out using traps which are believed to have only minor impact on the ecosystem. However, any harvest taken can influence the population biology of the species. High fishing pressure on the red king crab stock in Norway has probably changed the spawning stock demography and thereby the reproduction potential.

- Influence of development of renewable energy resources (e.g. wind, hydropower, tidal and waves) on marine habitat and biota

For many of the existing constructions there is no "before" – knowledge of the systems. This is particularly the case for offshore wind farms. There are many proposals for such wind farms, both in the UK, Norway and France, which could impact on *Cancer pagurus*, spider crab and lobster stocks and fisheries. The WG therefore requests (recommends) that baseline studies must be routinely carried out before any plans for renewable energy constructions in marine habitats are realised and that monitoring should continue during construction and especially after the plant has been commissioned.

Currently in France, wind farm areas have been selected and different companies respond to the tenders. In some areas, the fishing activities are important. The spider crab and the lobster are targeted in 2 of the selected areas.

Sandy area

For the spider crab, the questions about the impact are linked to the potential modification of the migration due to the power cable and the associated magnetic field.

Rocky area

For the lobster, the technique used to install the machine could destroy habitats or can generate a lot of perturbation during the construction increasing the turbidity in large space.

- Population and community level impacts of contaminants, eutrophication, and habitat changes in the coastal zone

Along the recent study on the contamination of crustaceans, Bodin (2005) analysed the presence of the organohalogenated contaminants in different species. Their capacity for bioaccumulation reaches higher level consumers, including humans. For humans, the consumption of marine organisms is considered as the most important source of contamination. The food agencies are particularly aware of the potential health effects.

Crustaceans from different areas have been analysed in order to estimate the level of contamination from compounds belonging to three organohalogenated families. The three families are the PCB (polychlorinated biphenyls), the PCDD/Fs (polychlorinated dibenzo-p-dioxins and bibenzofurans) and the PBDEs (polybrominated diphenyl ethers). Along the coast from the point of Brittany until the Eastern Channel, the level of the PCB is really high in comparison to the PBDE and PCDD. This situation characterizes the low level in the coastal water for the PBDE and PCDD. For the 3 compounds, the Bay of Seine is the area with the highest level of contamination, followed by the point of Brittany and the Bay of Granville. This situation is explained by the influence of the rivers in the different areas. The Seine River brings a lot of contaminants from industrial sites (Le Havre, Rouen, Paris). The level of contamination in different crustacean species is mainly linked to diet and behaviour. For each species, the hepatopancreas is the organ with the highest concentration of contaminants, due to the high lipid level. The compound level in each organ is positively correlated to the lipid level.

Recently (July 2011), a study showed that in the Bay of Seine, the edible crab and the velvet crab have a level of PCB and dioxin higher than European thresholds. The ANSES (National Agency for Safety) suggests forbidding the consumption of these 2 crustaceans. In parallel, additional analyses could be performed on spider crab too.

Currently in France, wind farm areas have been selected and different companies responded with interest to the suggested areas. In some of these areas, fishing activities are important. The spider crab and the lobster are targeted in 2 of the selected areas.

For the spider crab, the questions about the impact are linked to the potential modification of the migration due to the power cable and the associated magnetic field.

For the lobster, the technique used to install the machine could destroy habitats or can generate a lot of perturbation during the construction increasing the turbidity in large areas.

The Norwegian Food Safety Authority is presently conducting a national surveillance of the cadmium level in edible crabs in all of Norway. High values of cadmium have been registered in the area around Bodø in northern Norway, and it is not advised to consume these crabs. The present surveillance is carried out to investigate whether these high levels are limited to the Bodø-area or not, and potential sources are investigated (anthropogenic vs. natural levels in sediments etc).

Along the recent study on the contamination of crustaceans, Bodin (2005) analysed the presence of the organohalogenated contaminants in different species. Their capacity for bioaccumulation reaches higher level consumers, including humans. For humans, the consumption of marine organisms is considered as the most important source of contamination. The food agencies are particularly aware of the potentiel health effects.

The crustaceans becoming from different areas have been analysed in order to estimate the level of contamination from compounds belonging to three organohalogenated families. The three families are the PCB (polychlorinated biphenyls), the PCDD/Fs (polychlorinated dibenzo-p-dioxins and bibenzofurans) and the PBDEs (polybrominated diphenyl ethers). Along the coast from the point of Brittany until the Eastern Channel, the level of the PCB is really high in comparison to the PBDE and PCDD. This situation characterizes the low level in the coastal water for the PBDE and PCDD. For the 3 compounds, the Bay of Seine is the area with the higher level of contamination, following by the point of Brittany and by the Bay of Granville. This situation is explained by the influence of the rivers in the different areas. The Seine River brings lots of contaminants from industrial sites (Le Havre, Rouen, Paris). The level of contamination from different crustacean species is mainly linked to the diet and the behaviour. For each species, the hepatopancreas is the organ with the high level of concentration in association with the high lipid level. The compound level in each organ is positively correlated to the lipid level.

Recently (July 2011), a study shows that in the Bay of Seine, the *Cancer pagurus* and the velvet crab have a level of PCB and dioxin higher than European thresholds. The ANSES (National Agency for Safety) suggest to forbidden the consumption of these 2 crustaceans. In parallel, additional analyses could be performed on spider crab too.

- Introduced and invasive species, their impact on ecosystem and interaction with climate change processes

In Europe we have at least three large, invasive species: the red king crab (*Paralithodes camtschaticus*), the snow crab (*Chionoecetes opilio*) and the Chinese mitten crab (*Eriocheir sinensis*). The Working Group are considering the biology (and ecological impact) of both the red king crab and the snow crab in Europe (Barents Sea). New knowledge on the effects of the red king crab on the benthic ecosystem is recently established and research on the impact of both species will be continued in future, and forwarded to the WG.

- Marine living resource management tools

The implementation of biological reference points will be discussed on the next WG meeting. In addition, stock assessment models are under development for some of the crab stocks. This work will be continuously communicated to the WG. The management of crab stocks varies between stocks and between countries and improvement is a reiterate issue in the WG discussions.

- Marine spatial planning, including the effectiveness of management practices (e.g. Marine Protected Areas (MPAs)), and its role in the conservation of biodiversity

MPAs are applied for some crab stocks: edible crabs in France and snow crabs in Canada (buffer zones). The WG agreed that MPAs should have been more actively applied in crab management since it is possible to identify limited geographical habitats where vulnerable parts of a crab stock are located (e.g. soft shell crabs, juveniles, mating grounds etc.).

Annex 1: List of participants

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Annex 2: Agenda

ICES WGCRAB 2011, Copenhagen June 7th -9th.

Tuesday 7 June

0900 Welcome

- Housekeeping information by our secretary Maria Lifentseva
- Presentation of participants and a short review on ToRs.
- Status on the 2010 report
- Format og the WGCRAB report for 2011
- Adding planned oral presentations to the agenda.
- Appointment of rapporteurs

1000 ***ToR a***. Compiling data on landings, discards, effort and catch rates (CPUE) and provide standardized CPUE, size frequency and research survey data for the important crab fisheries in the ICES area.

Formatting new information for the standard format for the report

1030 – 1045 Coffee brake

1045 – 1300 ***ToR a***. Continued

1300 – 1400 Lunch

1400 – 1545 ***ToR b***. Evaluate assessments of the status of crab stocks, identify gaps in assessment programmes, and review the application of biological and management reference points for crab fisheries.

Request from Olive Tully to agree upon the assessment units for *Cancer pagurus* suggested last year.

1545 – 1800 ***ToR b***. Continued

Wednesday June 8

0900 – 1030 ***ToR b***. Continued

1030 – 1045 Coffee brake

1045 – 1300 ***ToR c***. Review data on estimates of natural mortality and other biological information for crabs that is required for providing standardized indices and for analytical assessments.

1300 – 1400 Lunch

1400 – 1545 ***ToR c***. Continued

1600 – 1800 ***ToR d***. Potential impact of introduced crab species and changes in the distribution of crab species in relation to climate change.

Thursday June 9

0900 – 1030 ***ToR d.*** Continued

1030 – 1045 Coffee brake

1045 – 1300 ***ToR e***. Review information on the incidence/prevalence of diseases in crab fisheries and review the extent to which bitter crab disease might affect the recruitment.

We need to discuss if this issue should be a task for this WG since diseases in fish and shellfish are dealt with by the ICES WGPDMO. What is the significance of this issue for the work of our WG and how do we deal with it in the future.

1300 – 1400 Lunch

1400 – 1545 ***ToR f***. Assess the contribution of the WG to the ICES Science Plan.

1545 – 1600 Coffee brake

1600 – Date and venue of the next meeting, AOB.

1800 Close of meeting

Annex 3: WGCRAB draft Terms of Reference for the next meeting

The **Working Group on the Biology and Life History of Crabs** (WGCRAB), chaired by Jan H. Sundet, Norway, will meet on the Isle of Man, UK, 14–18 May 2012 to:

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

b) Evaluate assessments of the status of crab stocks, identify gaps in assessment programmes, and review the application of biological and management reference points for crab fisheries. A specialist on these topics will be invited for the next meeting;

c) Review knowledge on stock parameters as indicators in assessments of crab stocks without fishery independent data, and other biological information on crab stocks required for providing standardised indices and for analytical assessments;

d) Review the potential impact of introduced crab species and changes in the distribution of crab species in relation to climate change;

e) Assess the contribution of the WG to the ICES Science Plan.

WGCRAB will report by 5 July 2012 (via SSGEF) for the attention of SCICOM.

Supporting Information

Priority	High. The fisheries for crabs are socio-economically important and trans-national in Europe and Canada with the demise of fin fisheries in some regions. Management of stocks in Europe is primarily by technical measures only and in most countries there are generally no management instruments to control fishing effort. Knowledge of the population dynamics of these species is also weak. These stocks may be at risk from over-fishing due to the lack of control on fishing effort, and hence an evaluation of the sustainability of these fisheries is necesasary. The activity of the Group is therefore considered to be of high priority in particular if it's activity can move towards resource assessment without losing biological inputs.
Scientific justification	a) and b) The European *Cancer*, *Maja* and *Paralithodes* stocks, and the Atlantic Canadian snow crab (*Chionoecetes*) stocks are apparently in a phase of steady state according to landings, but the CPUE vary from area to area. In addition, these fisheries are becoming more international in nature and more highly capitalised with the expansion of effort to offshore grounds. An increasing stock of the snow crab in the Barents Sea (new species in this area) are seen as a future prosperous fishing resource both in Russian and Norwegian zone in this waters. Although crab stocks are heavily fished and there is virtually no effort control in European fisheries, there is only minor changes in catch rates. An increased understanding of stock structure is necessary for a proper management of crab stocks, both nationally and internationally. Information on general biology as well as genetical studies and the physical environment, are critical in identifying the stock structure of crabs to ensure effective stock management. Several tagging experiments are carried out to enhance knowledgen on crab stocks. [Science Plan – Marine living resource management tools. Fish life history information in support of EAM]. c) Several stock parameters are important for analytical assessments. Biological information is therefore required to provide standardised indices and for use in analytical assessments. Crab stock parameters

	may change due to size selective and single sex fisheries, through by-catch in other fisheries or through the impact of other seabed uses, such as gravel extraction. Since important crab stocks in Europe are managed without fishery independent data it may be an option to investigate any useful stock parameter indicators for assessment purposes [Science Plan - Marine living resource management tools. Fish life history information in support of EAM]. d) The introduction of the red king crab (*Paralithodes camtschaticus*) to the Barents Sea in the 1960s is a classic example of an introduced species which has significantly changed the benthic ecosystem. Much can be learned from this introduction including the potential implications of likely changes in crab species distribution due to climate change. Decapod crustaceans are an abundant group of alien species worldwide. [Science Plan – Introduced and invasive species, their impacts on ecosystems and interaction with climate change processes – and – Biodiversity and the health of marine ecosystems.] e) The Working Group decided that diseases should not be a focused theme in the WG, but leave this issue to be handled by WGPDMO. Diseases are of great significance for the dynamics of crab stocks, and if necessary, members from WGPDMO will be invited to discuss actual problems regarding crabs to annual meetings of WGCRAB. f) The Group went through the requests in the ICES Science Plan and concluded that knowledge from research carried out amog the Group members corresponds to a major numbers of the topics in the Plan.
Resource requirements	Existing national programmes provide the main input for discussion. The level of activity and approaches taken in these programmes, and the participation of members from national institutes, determine the capacity of the Group to make progress.
Participants	The Group is normally attended by some 15 members and guests.
Secretariat facilities	None.
Financial	None specific.
Linkages to advisory committees	As the Group's work moves towards provision of peer-reviewed assessments for crab stocks, links with ACOM will be developed.
Linkages to other committees or groups	Some of the topics covered by WGCRAB relate closely to topics covered by SSGSUE.
Linkages to other organizations	None.

Annex 4: Working documents

Modelling the movements of edible crabs in the English Channel, Western Approaches and Celtic Sea. Mike Smith, Derek Eaton and Roslyn McIntyre, 2011. Cefas.

Results from the double T-bar and Data Storage Tag (DST) tagging programmes, together with results from aquarium experiments and commercially reported effort data, were used to quantify rates of movement by edible crabs in the study area and to estimate exploitation rates.

A population dynamics model similar to that developed during the EU POORFISH project (Smith, 2008, unpublished) was first considered for modelling the system dynamics, but it soon became apparent that with 3 seasons, 2 sexes and a matrix of 20 spatial units, the number of parameters to estimate was unmanageable. This model was therefore simplified to a single sex model with 2 seasons and 12 spatial units, based upon the distributions of tagged crab releases and recaptures and knowledge of the main fishing areas, which was applied separately for males and females.

Populations of tagged and released edible crabs were projected forward in monthly time steps. This provided 39 time steps for the first 'tag group', with subsequent tag groups introduced into the model at the appropriate time and location. Tag groups included both double T-bar tags, data storage tags (DST's) and small numbers of re-releases made by some fishermen. The latter were considered as normal recaptures and their release as a new introduction into the population. Releases of crabs tagged with data storage tags (DST's) had much higher return rates than double T-bar tags (approx. x2), so a parameter for differential return rate by tag type was included in the model.

Fishing effort data for each spatial unit and time step were retrieved from reported commercial data, aggregated to ICES rectangles and allocated to each spatial unit. Spatial units were nominal, of different sizes and did not correspond exactly with ICES rectangles. In some cases effort for a single ICES rectangle was apportioned into different spatial units, whilst in other cases a spatial unit consisted of effort from several rectangles. It was not possible to obtain fishing effort data for foreign vessels, and effort allocated in the 'catch-all' domain surrounding the spatial units could not be included because this area is unbounded. Crabs moving to this domain were 'lost' from the analysis and not included in the fitting objective function. The mobility of crabs is limited and the rationale used by Hilborn (1990) of limiting movement to contiguous spatial units in any one time step was followed. This also had the advantage of substantially reducing the complexity and the number of potential permutations for movement between areas.

Edible crab biology displays marked seasonality as well as differences between sexes, which complicates the modelling process. One notable feature is that due to their large egg mass and brooding behaviour, when ovigerous females have very limited mobility and therefore low catchability. The population model assumes 2 seasons, one corresponding to the main ovigerous season for females (December to May) and the other to the remainder of the year (June to November), when mature females are most mobile and which also includes the main period of fishing activity. Although male catchability does not show the same seasonality as females, the same 2 season model was used. Other biological features, such as the moulting and mating cycle, may impact on mortality, movement and catchability of crabs but the biology of these aspects is insufficiently quantified to meaningfully parameterise the model and therefore, in order to enhance parsimony, they were not modelled at this stage.

In order to retain the correct ratios between numbers of tags released and recaptured, all recaptures were used, although some did not have full temporal or positional data relating to recapture. These were apportioned among the possible spatio-temporal strata by utilising all available information about them and/or according to the proportions of valid returns for these strata.

The basic population equation of Hilborn (1990) was used along with modifications suggested by Aires-da-Silva *et al.* (2005) for including terms for tag loss and natural mortality

$$\hat{N}_{i,a,t+1} = \sum_{j=1}^{n} \hat{N}_{i,j,t}\left(1 - q_{j,s}E_{j,t}\right)e^{-(M+\lambda)}p_{j,a} + T_{i,a,t}$$

where $\hat{N}_{i,a,t}$ is the predicted number of tagged fish if tag group *i* present in area *a* at time (month) *t*,

$q_{j,s}$ is catchability for area *j* and season *s*,

$E_{j,t}$ is fishing effort in area *j* at time *t*,

$P_{j,a}$ is the probability of movement from area *j* to area *a*,

$T_{i,a,t}$ is the number of tagged crabs and released from group *i*, area *a* and time *t*.

The rate of tag loss for double T-bar tags was estimated (monthly λ=0.031) from 6 aquarium experiments and the rate of loss of data storage tags was assumed zero within the timeframe of the field tagging experiments. A double T-bar tag loss rate, estimated simplistically from field double tagging experiments was very similar but slightly lower in magnitude (0.019). However, this methodology did not take account of the potential loss of both tags, so will be an under-estimate of the overall double T-bar tag loss rate.

Monthly harvest rate in each area ($h_{j,t}$) is expressed as the product of seasonal catchability ($q_{j,s}$) and monthly effort ($E_{j,t}$)

$$h_{j,t} = q_{j,s}E_{j,t}$$

Return rates between the 2 types of tag used in the study differed widely and in common with Aires-da-Silva *et al.* (2005) a parameter for tag reporting rate (ψ_{2T} : double T-bar tag return rate relative to data storage tag return rate) was included and estimated as a parameter in the model fit. The observation model therefore becomes

$$\hat{R}_{i,a,t} = \hat{N}_{i,a,t}q_{a,s}E_{a,t}\psi_{2T}$$

where $\hat{R}_{i,a,t}$ is the predicted number of tags recovered from tag group *i* in area *a* at time *t*.

We use the Hilborn (1990) Poisson likelihood function which gives a total likelihood of

$$\prod_{i,a,t} \frac{e^{-\hat{R}_{i,a,t}} \hat{R}_{i,a,t}^{R_{i,a,t}}}{R_{i,a,t}!}$$

but for minimisation we use the simplified negative log-likelihood function suggested by Aires-da-Silva *et al.* (2005), in which the factorial *R* term has been dropped because it is constant.

$$\sum_{i,a,t} \left[\hat{R}_{i,a,t} - R_{i,a,t} log\left(\hat{R}_{i,a,t}\right)\right]$$

Using the logarithmic transformation also reduces problems with overflow that were encountered with some of the terms in the full likelihood function. The model was implemented in Excel workbooks supported by Visual Basic for Applications (VBA). Minimisations were carried out iteratively, using the Solver add-in under VBA control, until changes in the objective function were minimal. It is difficult to be certain that a stable and global minimum had been reached, particularly in a multi-dimensional problem such as this with so many parameters. Nonetheless, there was substantial change from the starting parameter values and results were generally sensible in most areas when considered in the context of the input data. Future work might involve including more complexity to the model (e.g. introducing a third season), but developing the model in an application with more powerful minimisation capabilities prior to this, such as AD Model Builder, would be preferable.

Data for males showed no recaptures beyond the nearest westerly neighbour, but as far fewer males were tagged or recovered than females, there is a lot more uncertainty in these results. Therefore, the following results refer only to females.

Model results suggested that within any one month most female crabs stayed in their 'current' area. There were exceptions; during the June–November season in the Lands End/Scilly and South Devon domains (Figure 1) and in December-May for areas of the western Channel south of the Devon and Cornwall coasts (Figure 2). However, even though within any one month and area the majority of the population remain stationary, the monthly movement rates were sufficiently high for all surviving female crabs to have completely moved out of the release area after several years. This scenario was clearly demonstrated by the input data matrix for females released in the eastern English Channel (Shingle Bank & Sovereign Shoals area). The shift in distribution of recaptures with time to areas further west was striking, with recoveries during the remainder of the release fishing season all local (except 1 to the easterly neighbour), in the first year after release most recoveries were in the release area with some in areas further west, 2 years after release most were further west with few in the release area and 3 years after release all were further west with none in the release area. The seasonality of the fishery was also clearly shown with most recoveries occurring between June and December. The implication is that over 3 to 4 years, all surviving females from eastern Channel releases had all left the release area and moved to fishing grounds in the western Channel, and that crab populations in the eastern Channel are net exporters of adult females to the western Channel.

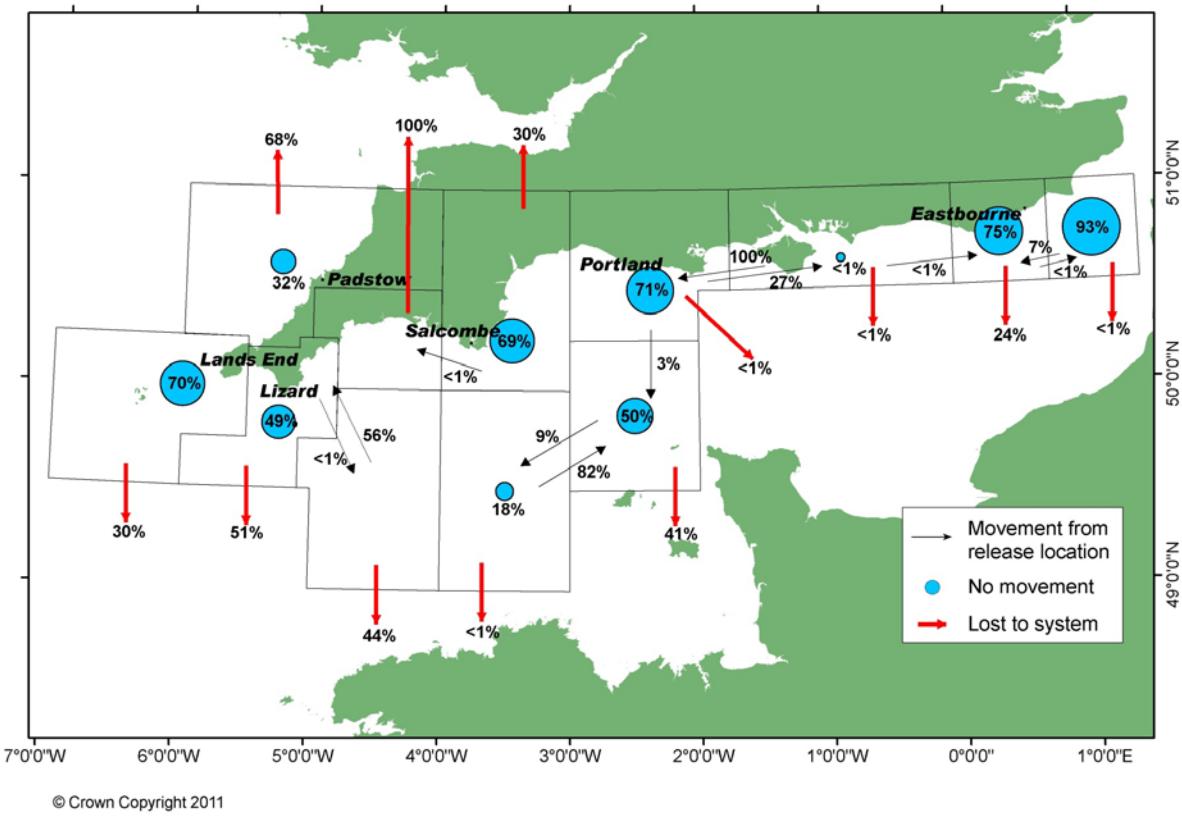

Figure 1. Predicted monthly rates of movement for female crabs; June–November.

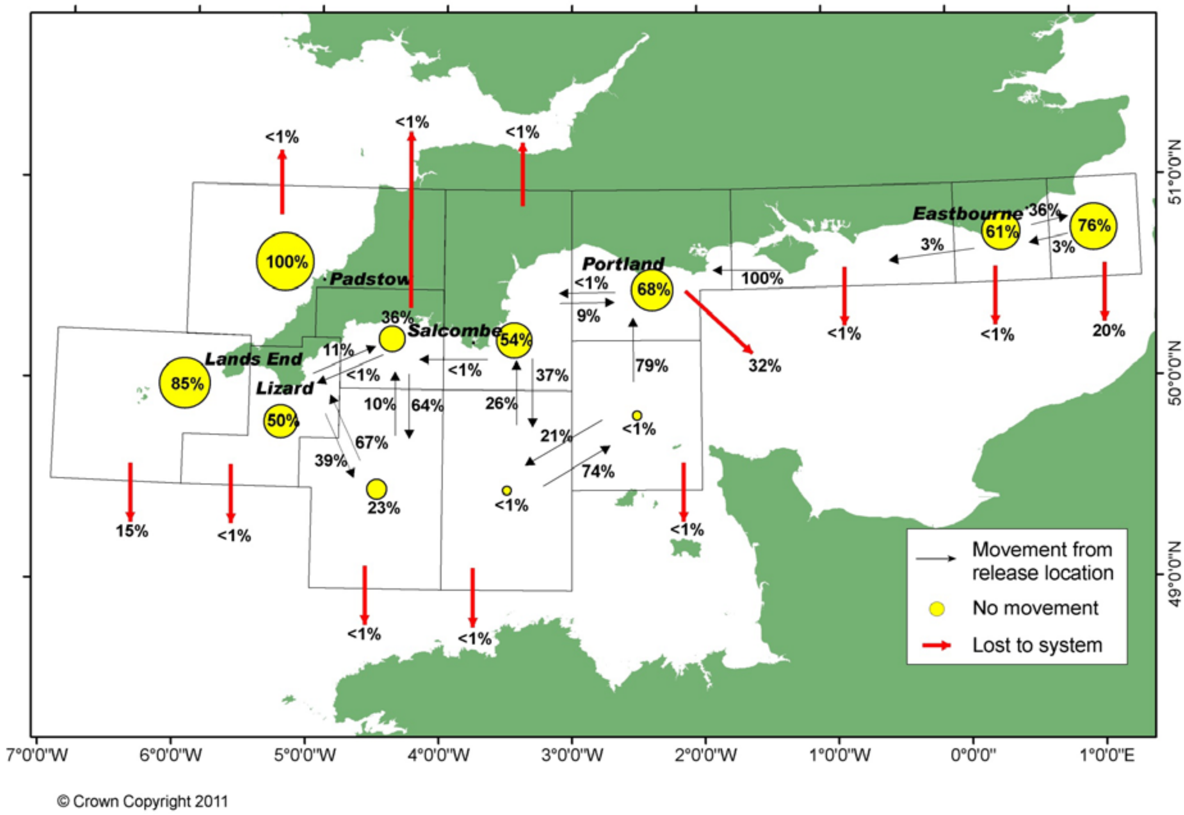

Figure 2. Predicted monthly rates of movement for female crabs; December–May.

Although some movements predicted by the model are realistic, given our knowledge of the behaviour of female crabs and especially that related to the reproductive cycle, other predictions are counter-intuitive and likely to be erroneous. In particular the high rates of movement of female crabs from the Lands End & Scilly fishery area into the Lizard area during the summer & autumn for which there is no evidence from the tag returns. The areas where modelled movement predictions did not accord with physical observations were also sinks in the model system, losing a large proportion of crabs each month. Bearing this in mind these unsupported results should be treated with extreme caution. It is worth reiterating that far fewer male crabs were tagged and recovered than females and the results for males especially need to be treated with some caution.

Generally, and more particularly for females, many expectations produced by the model are informative and may help to quantify the rates of transfer of crabs between some areas. The model predicts that the majority of female crabs remain in their current area in any one month in almost all areas and although it does not always highlight strongly the westward patterns of movements suggested by many of the tag recaptures, close consideration of the outputs shows that the model dynamics can accommodate these westerly migrations which occur over a protracted time scale. Other, model outputs suggest some easterly movements that are not supported by any physical evidence from either the double T-bar or DST tagging programmes and are almost certain to be erroneous. In its current form it appears that the model may at times force population movements to accommodate changes in recapture rates and distribution that may be due to changes in catchability related to the reproductive cycle, or result from anomalies in the data such as different reporting rates between areas and through time. Future work will include considering alternative spatial and temporal scales to optimise contrast in the data.

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Female size-fecundity relationship in the introduced Red King Crab (*Paralithodes camtschaticus*, Tilesius) population in Norwegian waters

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Background

The red king crab was introduced to the Barents Sea by Russian scientist during a period of 10 years in the 1960s. Their overall aim with the introduction was to improve coastal fishery and thus improve the local economy. The introduction program focused on mature individuals, and larvae and juvenile crabs reared in marine laboratories was also released into the sea. In January 1977 the first catch of red king crab was done in Norwegian waters. Since then the size of the population and areas occupied by the species has increased. Today there is a valuable fishery for red king crab, and we want study if the fecundity in any way is affected by the changes in the abundance of the crab change, which can be of importance for the management.

Material and methods

In this study of the female size-fecundity relationship in red king crab, egg samples from 874 females caught during autumn scientific cruises in the main distribution area for king crabs has been analysed. Sampling period was from 2000 to 2007, and the main focus has been on three large fjords in the distribution area (Varangerfjorden, Tanafjorden and Laksefjorden). Egg clutches were sampled from 1–10 individuals in each 10 mm size groups to ensure representative selections from the available size range present at sampling time. The total egg mass was stripped off the pleopods, and three subsamples were chosen for egg counting under the microscope. The individual dry weight of an egg (IEW) estimated formed a basis for the estimate of the total number of eggs. The red king crab female reproductive output (RO) was calculated using the ratio between the total dry egg mass weight and the body volume.

Two datasets were analysed with regard to effect of year and area (fjord). Data from Varangerfjorden and Tanafjorden was available from 2000 to 2007 (dataset 1), and data for all three fjords was available for the period 2004 to 2007 (dataset 2).

Results and discussion

The size range of the 874 ovigerous females in the analyses was 93–187 mm CL. The total number of eggs varied from 18 000 to the highest number 477 000 eggs. The mean number of eggs in each fjord varied from 176 000 to 219 000 eggs. The size composition among the ovigerous females in dataset 1 during the sampling period seems to have changed, and the size span has decreased from 173 and 178 mm CL in 2000 to 144 mm CL in Varangerfjorden and Tanafjorden respectively in 2007. The analysis of fecundity related to size showed that number of eggs increased significantly with female size for each fjord and year examined. There were annual differences in fecundity in Varangerfjorden and Tanafjorden for the period 2000–2007, and differences in fecundity related to size in the two fjords were also found.

For dataset 2 no effect of year within the three fjords was found, but difference between the fjords was seen. The data could therefore be pooled for each fjord. In order to visualize the fecundity in each fjord and year, a representative female size was defined and her fecundity was displayed showing a decreasing fecundity during the sampling period throughout the sampling area. The analysis of individual egg weight (IEW) showed differences between the fjords, with Laksefjorden having the heaviest eggs. Within the fjord the IEW was not influenced by female size.

The analysis of RO for the two datasets showed that RO was dependent on fjord, year sampled and the size of the crab. As for IEW, the highest values of RO were found in Laksefjorden.

This study has shown both temporal and spatial differences in fecundity within the population of red king crab. It seems that areas where the crab has been the longest and where the fishery pressure has been heaviest, the fecundity has changed. Other parameters as food availability and temperature regimes can also influence on fecundity and can be discussed to explain the alteration.