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Summary

This report provides updated fishery information and regional stock assessments for brown crab (*Cancer pagurus*), velvet crab (*Necora puber*) and lobster (*Homarus gammarus*) stocks in Scotland, based on data from 2006 to 2008. A more detailed description of Scottish creel fisheries and species biology is provided by Mill *et al*., 2009.

The Fisheries

- The Scottish creel fisheries are long established and tend to be mixed species with brown crab, velvet crab and lobster as the main target species. The importance of each species varies regionally and in relation to season and market demand. The landings of the combined crab and lobster fishery into Scotland were 12,800 tonnes in 2008 with a first-sale value of over £26M.

- **Brown crab:**
  Brown crab is the most commercially important species with landings in 2008 in excess of 9,000 tonnes and a first-sale value of over £10.8M. The principal fishing areas for brown crab in Scotland are the Hebrides, Sule, South Minch and Orkney. Landings from the offshore areas Sule and Papa have increased since the mid to late nineties and in 2008 accounted for 28% of the Scottish fishery.

- **Velvet crab:**
  Fisheries for velvet crab have assumed greater importance for Scotland in recent years. In 2008, 2,800 tonnes were landed into Scotland, with a value of £6.1M. Over 50% of the landings came from Orkney and the South Minch.

- **Lobster:**
  The total tonnage of lobster landed in Scotland has always been much less than that of crab but the average value per tonne is much higher. In 2008 landings were over 900 tonnes and the fishery was worth £9.8M. In recent years, the majority of landings have been from the South East, East Coast, Hebrides, Orkney and South Minch.

Stock Assessments

- Length Cohort Analysis (LCA) is the method used for assessing Scottish crab and lobster stocks. It uses landings length frequency data (collected as part of Marine Scotland – Science's market sampling program) raised to reported landings. Assessments are conducted on a regional basis and males and females are assessed separately.

- For the period between 2006 and 2008, LCAs were conducted for each species (with sufficient data) by assessment area, and the stock status evaluated in terms of growth overfishing by comparing estimated fishing mortality with F_{MAX}, the fishing mortality rate associated with maximum yield-per-recruit.

- **Brown crab:**
  Assessments for brown crab showed that the majority of stocks were being growth overfished to some extent, especially male stocks. Of the areas of major importance for brown crab landings, fishing mortality was estimated to be significantly above F_{MAX} for both males and females in the Clyde, South Minch and South East areas whilst in the Hebrides and Sule, fishing mortality was around F_{MAX}.

- **Velvet crab:**
  Velvet crab assessments indicated that in the Hebrides, Shetland, East Coast, and South East, stocks were being fished below or around F_{MAX} whilst velvet crab stocks in Clyde, Orkney and South Minch were being fished at levels significantly above F_{MAX}.

- **Lobster:**
  LCA assessments for lobster show that both male and female lobsters in the Clyde, East Coast and South East were all being fished above F_{MAX}. In the Hebrides, Ullapool and Orkney, males were being growth-overfished fished whilst females were being fished at or just below F_{MAX}. In Shetland, females were being fished slightly above F_{MAX}.

- Temporal trends in landings length frequencies and average size of the largest 20% of individuals were explored for the first time in an attempt to obtain further information on variations in recruitment and fishing mortality. In a number of well sampled areas (e.g. brown crab in the Orkney and velvet crab in the Hebrides) trends are apparent which could be associated with changing exploitation rate or recruitment whilst in other areas (e.g. Shetland for brown crab or Orkney for velvet crab and lobster) the length frequency data appear relatively stable suggesting a stable stock and fishery.

Data Requirements

1. With the exception of Shetland, where effort data are routinely collected, very limited useful effort data (pots fished) are currently collected from creel fisheries in Scotland. If available, landings-per-unit-effort could potentially be used as an index of abundance and provide information on stock dynamics.

2. The population structure and some aspects of the biology of crab and lobster are not well understood and some of the assessment areas as currently defined may be inappropriate. Brown crab tagging studies carried out in 2009 and 2010 to the north of Scotland suggests links between the offshore stock at Sule and inshore Orkney waters.

3. Discards in crab and lobster fisheries are sampled only on an irregular basis. Discard data are not essential to LCA (assuming that there is no discard mortality). However, more regular sampling and information on catches of undersized animals could provide an indication of inter-annual variation in recruitment.

4. Understanding the economic and environmental factors which influence fishers' decision making with respect to fishing location and target species would help with the interpretation of the temporal changes in landings and catch-rates.

5. Alternative approaches could be used to obtain more detailed information on creel fishing areas such as mapping fishing activity and identifying important crab and lobster habitat. A recent EU funded study has piloted a number of brown crab data collection initiatives (including the use of GPS loggers and fishermen's knowledge) which should improve understanding of fishery distribution and factors affecting the fishery.

6. Instead of a reliance on a single assessment technique such as LCA, the development of new measures or indices (for example landing per unit effort or recruitment) to inform about stock status and stock dynamics could improve the assessment of crab and lobster stocks.

1. Introduction

The Scottish creel fishery for crab (brown and velvet) and lobster is economically very important to Scotland. In 2008 the combined species landings of 12,800 tonnes had a value at first-sale of over £26M, the fifth highest in Scotland (Scottish Government, 2009). The fishery is long established and was traditionally an inshore mixed species fishery, prosecuted by small vessels. However, improved technology (enabling more effective storage of live animals) in the 1980s led to the development of an offshore fishery specifically targeting brown crab. In addition, the development of new markets for both brown and velvet crab have resulted in a substantial increase in the Scottish landings of both species over the last thirty years.

The crab and lobster fisheries are not subject to EU TAC regulations or national quotas although there are measures in place to restrict the fishing effort (kW days) of all vessels ≥ 15 m (including creel boats) in ICES Subarea VI (Council Regulation (EC) No 1415/2004). In addition, EU technical conservation measures (Council Regulation (EC) No 850/1998) include geographically varying minimum landing sizes (MLS) and restrictions on the amount of crab claws that can be landed. In Scotland, vessels landing crab and lobster are required to have a license with a shellfish entitlement. Vessels without this entitlement are only allowed to land limited amounts (25 crabs and 5 lobsters per day).

Length Cohort Analysis (LCA), (Jones, 1984), is the method used for assessing the Scottish crab and lobster stocks. It is a commonly used method of assessing fish or shellfish stocks for which commercial catch length frequency distribution data are available. LCA has been used by Marine Scotland Science (MSS) in previous assessments of the Scottish crab and lobster stocks (Mill *et al*., 2009; Kinnear, 2003; Chapman, 1994) and also by the NAFC Marine Centre to assess crustacean stocks around Shetland (Leslie *et al.,* 2007*;* Mouat *et al*., 2006).

The LCA method uses the commercial catch size composition data (total landings and length frequency data) along with estimates of growth parameters and natural mortality to estimate total stock biomass and fishing mortality at length. The results are presented in terms of stock biomass and yield-per-recruit relative to changes in fishing mortality. This approach gives an indication of the exploitation of the stock in terms of growth overfishing, but not recruitment overfishing.

This report provides an update of regional (Figure 1, updated from Thomas, 1958) stock assessments and fishery trends for crab and lobster stocks around Scotland. In addition, we have for the first time, explored temporal trends landings length frequency data in mean size. In theory, size based indicators can track the direct effects of fishing pressure on a population, although they may be confounded by environmental effects and sampling/data effects. A declining trend in the mean size can be associated with a reduction in the abundance of large individuals due to the effects of size selective fishing mortality, but may also reflect an increase in the number of small individuals in the population as a

consequence of strong recruitment. To mitigate the effects of variable recruitment, trends in the mean size of the largest 20% of individuals in the sampled landings were examined. High proportions of small individuals in the landings in particular years may be indicative of increased levels of recruitment to the population. These investigations into the trends observed in the landings size frequency data are still at an exploratory stage and are presented in this report for the first time. It should be noted that this type of analysis attempts to draw conclusions about trends in population size structure from landings size structure information. Clearly, many of the observed changes in landings size structure discussed above could actually be caused by changes in fishing practices (e.g. retention size) as well as changes in actual population size structure. Therefore inferences made from these types of analysis should be treated with a certain amount of caution.

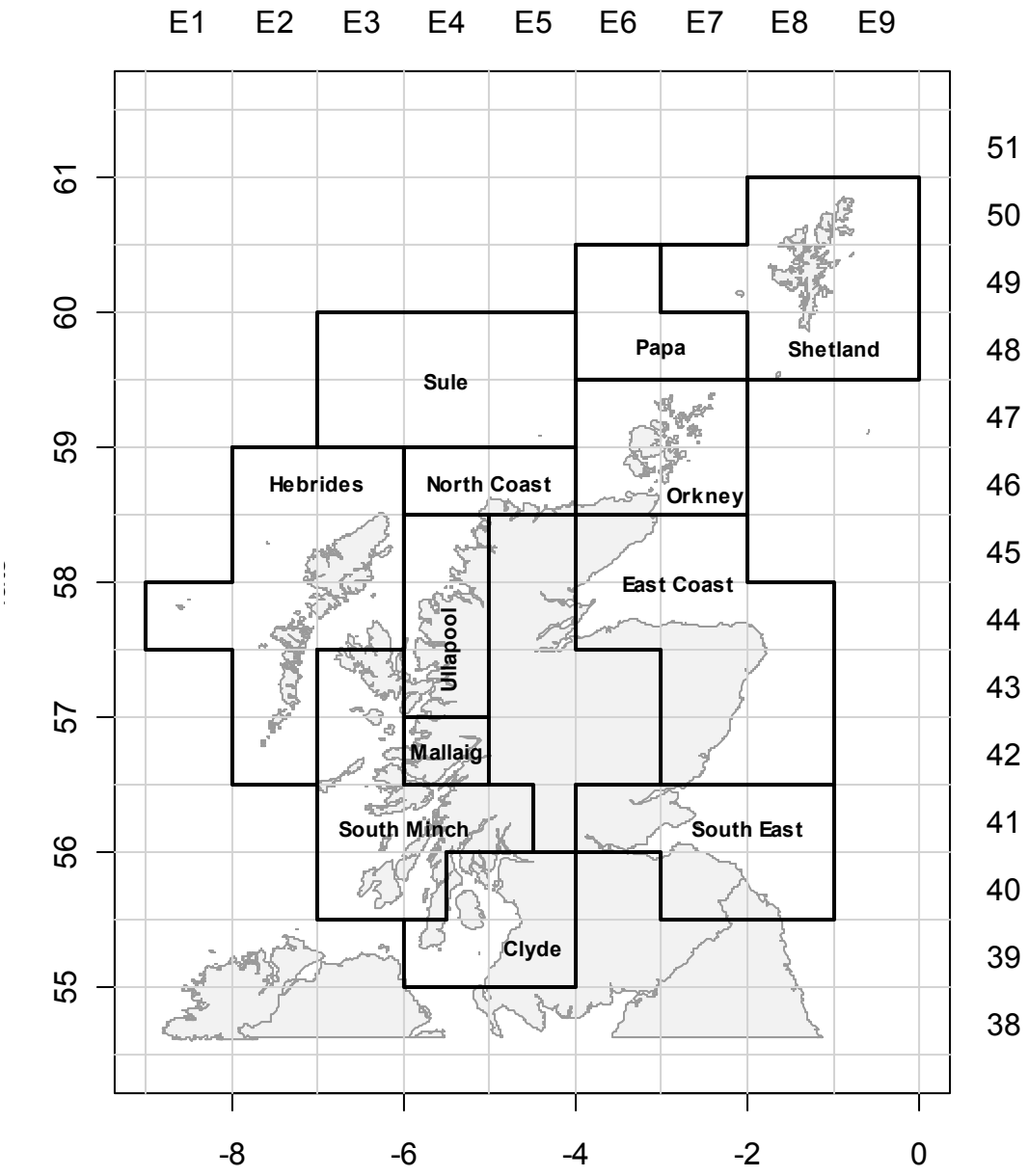

Figure 1: Crab and lobster fishery assessment areas in Scotland.

2. Methods and Data Sources

2.1 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 and in MSS Fisheries Management Database (FMD). Data for brown crab landings from the Republic of Ireland (collected by the Irish Sea-Fisheries Protection Authority (SFPA)) were compiled and provided by the Irish Marine Institute. The Irish data were not used for assessment purposes but to illustrate brown crab landings by nation on a statistical rectangle basis for the west coast of Scotland.

2.2 Numbers at Length

Length-frequency data were collected by MSS as part of its market sampling programme. The data are held in the MSS Fisheries Management Database (FMD). The numbers of each species measured in each assessment area, from 2006 to 2008 are shown in Table 1 and Table 2 contains information on the number of landings sampled for each species by assessment area. In general, sampling is focused in those areas where fisheries are most important. However, the timing of landings is rather unpredictable and sampling is to some extent opportunistic, factors which explain the variability in numbers sampled and the occurrence of zeros for certain species in some areas. Brown crab are typically retained for a period of time in holding tanks after being landed which makes them much easier to access for sampling.

Table 1

MSS Market sampling statistics, number of animals measured in each assessment area, 2006-2008.

Species	Year	Clyde	East Coast	Hebrides	Mallaig	North Coast	Orkney	Papa Bank	Shetland	South East	South Minch	Sule	Ullapool
Brown crab	2006	0	949	1322	0	649	1098	622	3230	1850	519	1705	198
	2007	776	2083	1217	0	109	2181	0	767	1549	242	3813	0
	2008	830	1340	2782	0	853	3042	0	519	4765	410	873	194
Velvet crab	2006	0	0	1031	0	0	7361	0	0	1402	494	0	0
	2007	473	1113	2658	0	0	9019	0	0	580	344	0	0
	2008	389	480	1143	0	0	6712	0	0	1286	170	0	0
Lobster	2006	359	92	1447	0	61	264	132	0	1896	0	0	557
	2007	77	585	1016	0	28	1330	0	0	904	37	0	135
	2008	254	566	1472	0	76	759	0	0	1553	29	0	0

Table 2

MSS Market sampling statistics, number of landings sampled in each assessment area, 2006-2008.

Species	Year	Clyde	East Coast	Hebrides	Mallaig	North Coast	Orkney	Papa Bank	Shetland	South East	South Minch	Sule	Ullapool
Brown crab	2006	0	7	3	0	1	5	1	15	13	2	2	1
	2007	3	15	11	0	1	15	0	4	20	2	3	0
	2008	7	10	10	0	2	19	0	3	42	3	3	1
Velvet crab	2006	0	0	5	0	0	23	0	0	7	1	0	0
	2007	2	6	12	0	0	36	0	0	3	2	0	0
	2008	2	3	5	0	0	29	0	0	7	1	0	0
Lobster	2006	1	1	12	0	1	5	1	0	34	0	0	2
	2007	2	7	8	0	1	28	0	0	24	1	0	1
	2008	6	7	11	0	1	24	0	0	23	1	0	0

Length is measured as carapace length (CL) for lobsters, from the eye-socket to the centre of the base of the thorax, and as carapace width (CW) for brown and velvet crabs, measured across the widest part of the body, not including any spines (see The Undersized Lobsters

(Scotland) Order, 2000, The Undersized Edible Crabs (Scotland) Order, 2000 and The Undersized Velvet Crab Order, 1989 for diagrams).

2.3 Raising the Data

Length frequency data obtained from market sampling and official landings data were combined to provide a raised annual catch-at-length distribution for input into LCA. This was 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 were then combined to give total annual raised length frequencies for each sex. Data were averaged over a number of years (2006-2008) and aggregated into 5 mm length classes for brown crabs and lobsters and 3 mm length classes for velvet crabs for use in the LCA.

2.4 Shetland Regulated Fishery Data

Following the granting of the Regulating Order for Shetland fisheries in 1999, fisheries data have been collected by the Shetland Shellfish Management Organisation (SSMO) as part of a mandatory log book scheme. Licensed fishermen return the completed log sheets to the SSMO where the data are collated and anonymity is ensured. They comprise relatively fine scale catch and effort data, reported by 5 mile squares to the SSMO (cf. 30 nm^2 for statistical rectangles in FIN). Shetland Shellfish Management Organisation landings data have been used by the NAFC Marine Centre to carry out annual assessments (Leslie *et al*., 2007; Mouat *et al.*, 2006) and these data were provided by the NAFC Marine Centre, with permission from the Shetland Shellfish Management Organisation, for use in this report. There is some disparity between the landings data recorded by the SSMO and the official landings statistics as recorded in FIN. This may in part be due to the differences in the way in which data from the under 10 m fleet are recorded (Mouat *et al*., 2006) and the spatial scale over which the data are collected. It appears that not all landings data from the Shetland area were entered into FIN between 2000 and 2005, possibly due to under-reporting of landings before the introduction of 'buyers and sellers' legislation. From 2006 onwards, FIN landings are greater than those from the SSMO which do not include non-SSMO vessels fishing in the offshore waters of the Shetland area.

Landings data from both sources (FIN and SSMO) are presented here for the period 2000-2008. For the LCAs of the velvet crab and lobster stocks in Shetland, the raised length-frequencies provided by NAFC Marine Centre (with the permission of the SSMO) were used as they have much greater sampling levels than MSS for these species in this area. The NAFC Marine Centre lobster length frequency distributions were obtained from market sampling while the velvet crab length frequencies were obtained from sampling onboard commercial vessels and represent length frequencies of the catch (discards and landings). These data were raised to the fleet landings and aggregated as described above for the MSS length frequency data.

2.5 Biological Parameters

Information about the growth of British crabs and lobsters comes mainly from tagging studies carried out in the 1960s and 70s (Hancock and Edwards, 1966; Hancock and Edwards, 1967) (Table 3). Estimates of the von Bertalanffy growth parameters: asymptotic length (L_∞) and instantaneous growth rate (K) have been estimated using Ford-Walford plots (Chapman, 1994; Tallack, 2002; Mouat *et al.*, 2006). Length-weight relationships (parameters *a* and *b* shown in Table 3) are from MSS (unpublished) market sampling measurements of length and weight. Different, area specific, biological parameters were applied in Shetland assessments as these are available from research on these species conducted in Shetland (see Leslie *et al*., 2007 for data sources). To account for the differences in growth and length-weight relationships (Table 3), sexes were assessed separately. The results of LCA are presented in the form of yield-per-recruit (Y/R) and biomass-per-recruit (B/R) curves, where changes in equilibrium stock biomass and landings (yield) are plotted against the percentage change in fishing effort (analogous to fishing mortality).

Table 3

Biological parameters used in stock assessment for brown crab, velvet crab and lobster.

		Growth parameters		Length-Weight relationship		Terminal group Fishing effort	Natural 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
Shetland	Males	0.188	246	0.00008	3.166	0.406	0.242	Tallack, 2002
Shetland	Females	0.224	227	0.00024	2.895	0.174	0.256	Tallack, 2002
Necora puber								
	Males	0.105	103	0.0003	3.0389	1.9	0.1	Chapman, 1994
	Females	0.118	100	0.0009	2.7405	1.1	0.1	Chapman, 1994
Shetland	Males	0.463	107	0.0011	2.75	0.31	0.576	Tallack, 2002
Shetland	Females	0.463	100.1	0.0038	2.42	0.202	0.576	Tallack, 2002
Homarus gammarus								
	Males	0.11	173.4	0.000126	3.36	0.5	0.1	Chapman, 1994
	Females	0.13	150	0.000919	2.922	0.5	0.1	Chapman, 1994
Shetland	Males	0.112	188	0.0017	2.797	0.316	0.1	Mouat *et al.*, 2006
Shetland	Females	0.136	184	0.0004	3.123	0.452	0.1	Mouat *et al.*, 2006

Generally, lower levels of fishing effort will result in an increase in stock size and a reduction in landings. Higher levels of fishing effort will reduce total stock biomass but landings may also fall, as animals are caught before they have had time to grow to a size that would contribute much weight to the yield (growth overfishing). In between these lies an effort level that is optimum (F_{MAX}), giving the maximum yield-per-recruit to the fishery. The changes that the LCA predicts are long term (equilibrium). The method does not provide any indication of short-term stock dynamics or recruitment over-fishing (rate of fishing above which the recruitment to the fishery becomes significantly reduced).

3. Results

3.1 Landings Data: Regional and Temporal Trends

This section of the report describes long-term trends in the landings data for each of the three species, both at a national level and for each assessment area. It is difficult to establish how accurate the pre-September 2005 data are as in some areas landings are thought to have been under recorded before the introduction of 'buyers and sellers' legislation. However, assuming that there have been no systematic temporal differences in reporting practices (except for the effect of buyers and sellers from 2006 onwards), the historical reported landings data should provide useful information about temporal trends in landings and the relative importance of the species across the different assessment areas.

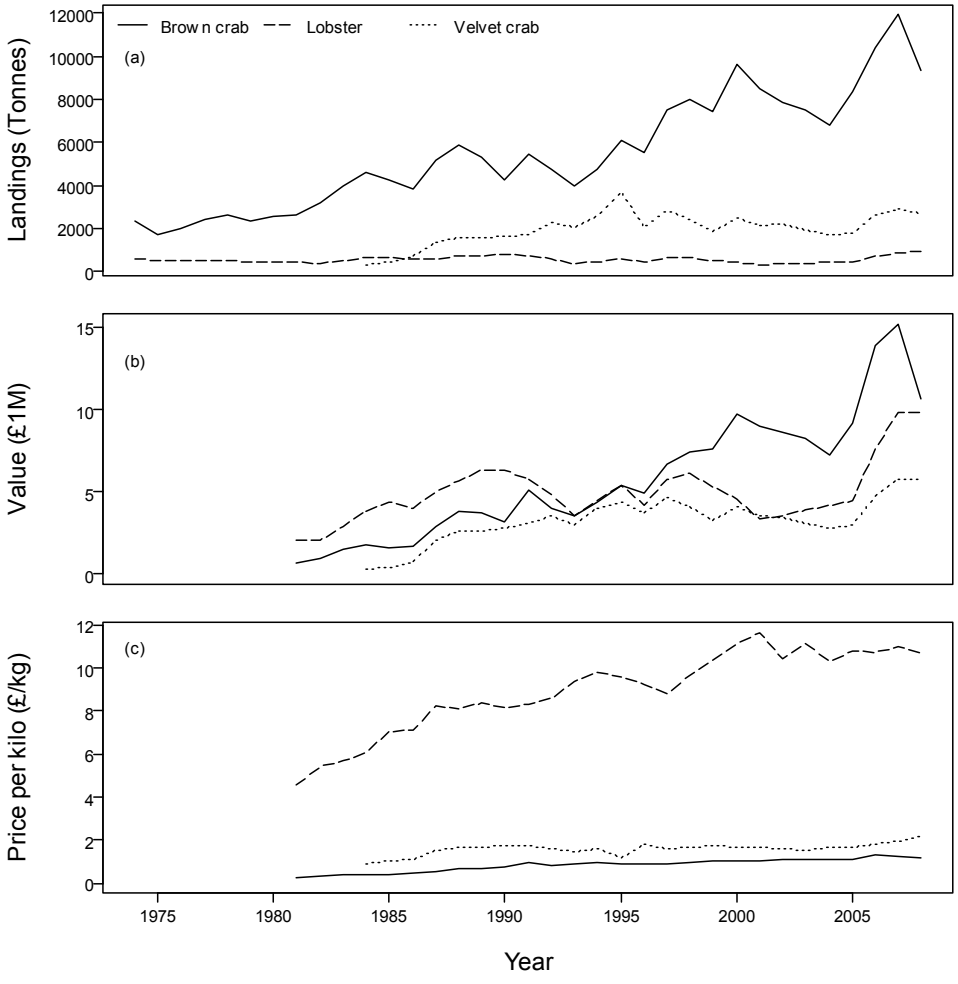

Figure 2: Crab and lobster fishery statistics 1974 -2008, a) Landings (tonnes) time-series by species, b) total landings value by species (£IM), and, c) price per kilo (£/kg) by species for brown crab, velvet crab and lobster. Data sourced from Fisheries Management Database.

During 1992 and 1993 there was a period when landings were not reported through official channels in the Orkney area. The regional time series data for all three species (Figure 3, Figure 5 and Figure 7), reflect this.

Brown Crab

Since the 1970s, brown crab landings have shown an overall increasing trend. Reported landings averaged around 2,000 tonnes in the late 1970s, increased to a maximum of about 12,000 tonnes in 2007 and subsequently decreased in 2008 to 9,400 tonnes (Figure 2a). There is little information on changes in fishing effort over the past 30 years, but it is likely that technological advancement and mechanisation of fishing and processing have allowed the fishery to expand and effort to increase. The emergence of a European market due to the ability to transport live crab and lobster has increased the demand. Larger vessels are able to fish previously unexploited crab stocks particularly those in the offshore area to the north of Scotland. The value of landings has increased in line with the tonnage landed. However, the price per kg has changed little over this time (Figure 2b and Figure 2c). One kilogram of brown crab was sold for an average of £1.25 at first sale during the period 2006 to 2008.

The spatial distribution of brown crab landings is shown in Figure 4. The principal fishing areas for brown crab in Scotland are Hebrides, Sule, South Minch and Orkney; landings from these areas account for over 60% of the total (Figure 3). Landings from the offshore areas of Sule and Papa have increased since the mid to late nineties and in 2008 accounted for 28% of the Scottish fishery (Table 4). Landings from the Orkney area exhibit a decreasing trend over the last 10 years.

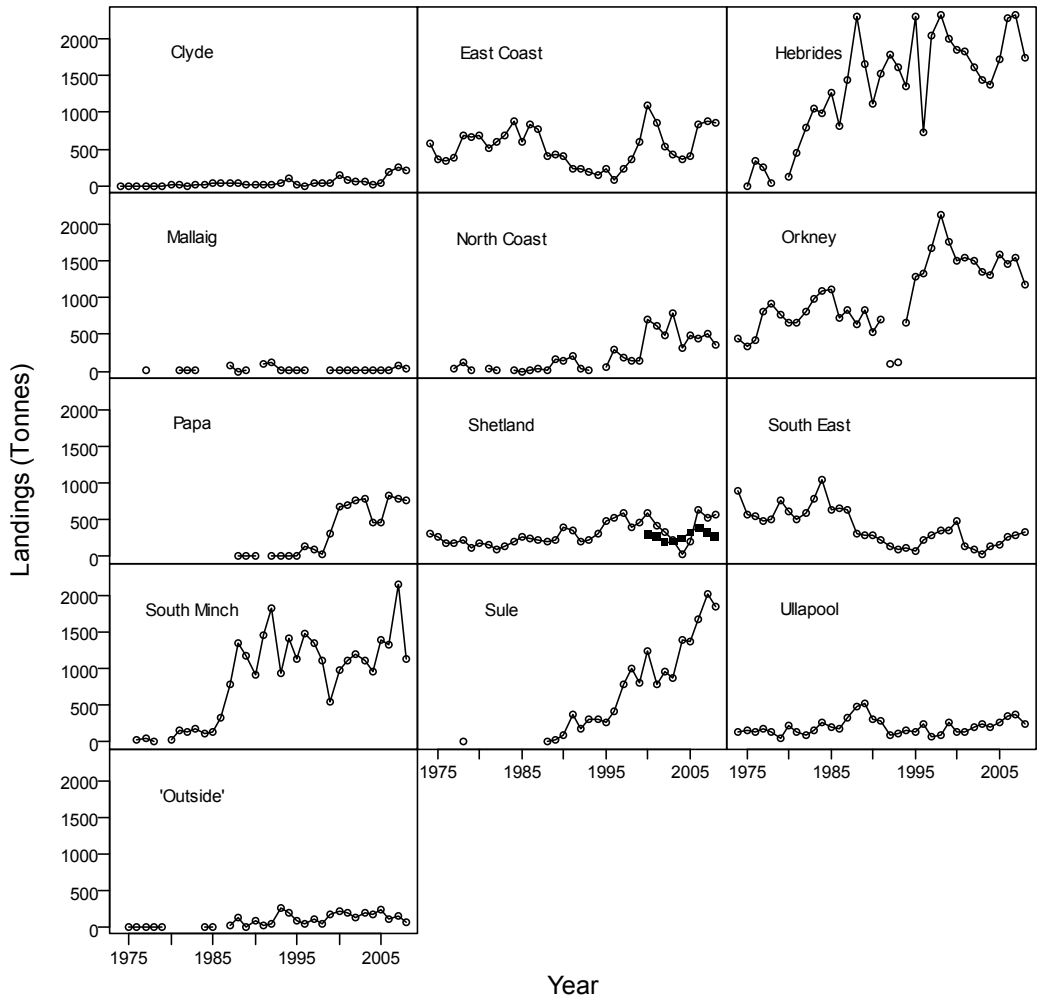

Figure 3: Annual brown crab landings (tonnes) into Scotland by assessment area 1974-2008. Data from the Fisheries Management Database; Data in black filled squares for Shetland (2000-2008) are from Shetland Shellfish Management Organisation logbooks (supplied by NAFC Marine Centre with permission from the Shetland Shellfish Management Organisation). 'Outside' relates to brown crab landed outside MSS crab and lobster assessment areas; see Figure 1 for area locations.

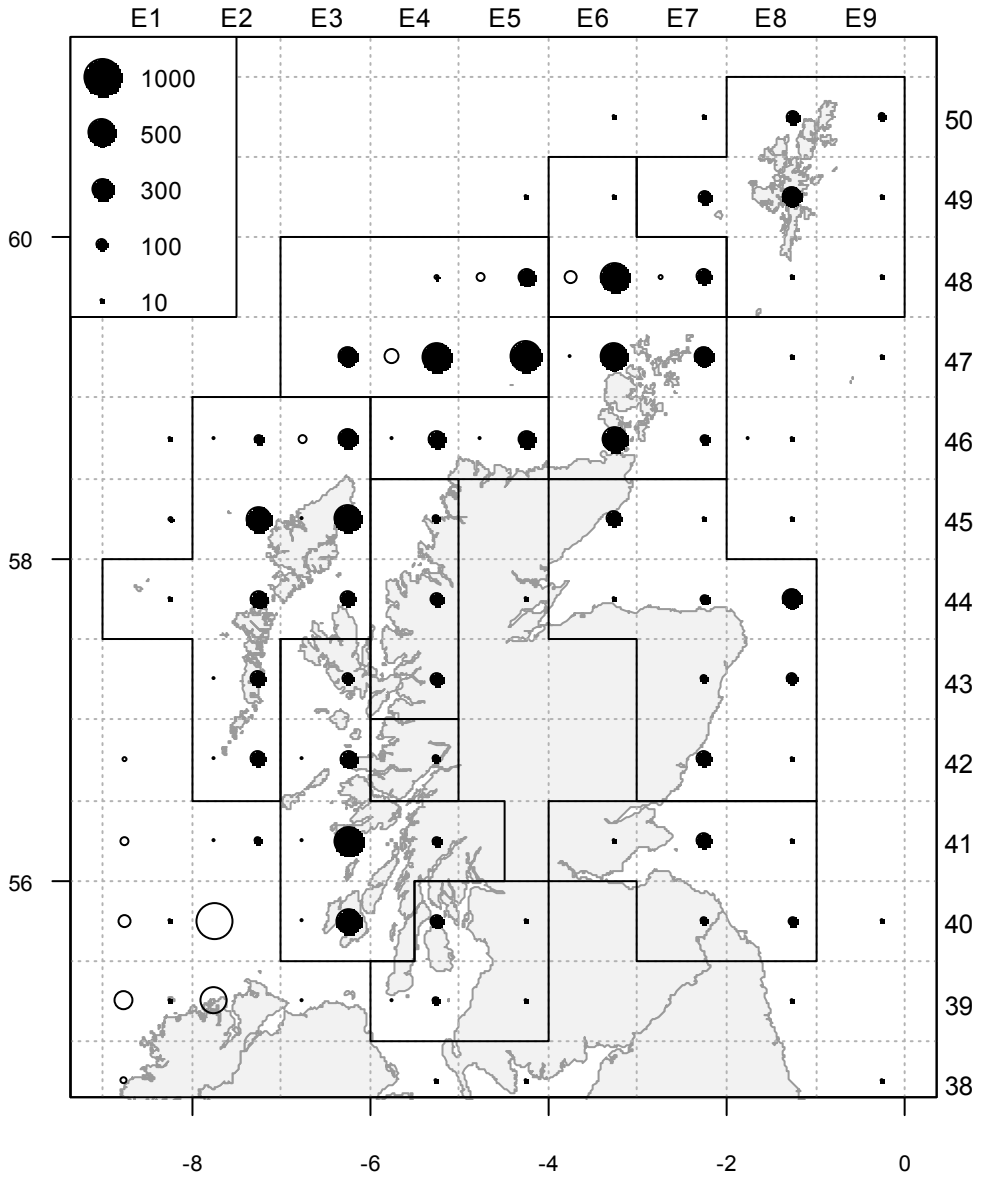

Figure 4: Average brown crab landings (tonnes) by statistical rectangle between 2006 and 2008. Filled circles represent landings into Scotland. Data are from Fisheries Management Database. Open circles represent landings into Republic of Ireland – data collected by SFPA, Rep. of Ireland (provided by the Irish Marine Institute).

Velvet Crab

Commercial exploitation of velvet crab was first documented in 1984 when a kilogram cost £1.06 on average at first sale. In 2008 the value had increased to £2.15 per kilogram and annual landings into Scotland were about 2,000 tonnes (Figure 2a). The three areas which have historically had significant velvet crab fisheries are the Hebrides, Orkney and South Minch (Figure 5). Figure 6 shows the spatial distribution of landings averaged over 2006-2008. Reports from the fishing industry suggest that the abundance of velvet crab on

the east coast of Scotland has increased in recent years. Landings from the East Coast and South East areas were 13% and 6.8% of the total Scottish landings in 2008, respectively (Table 4).

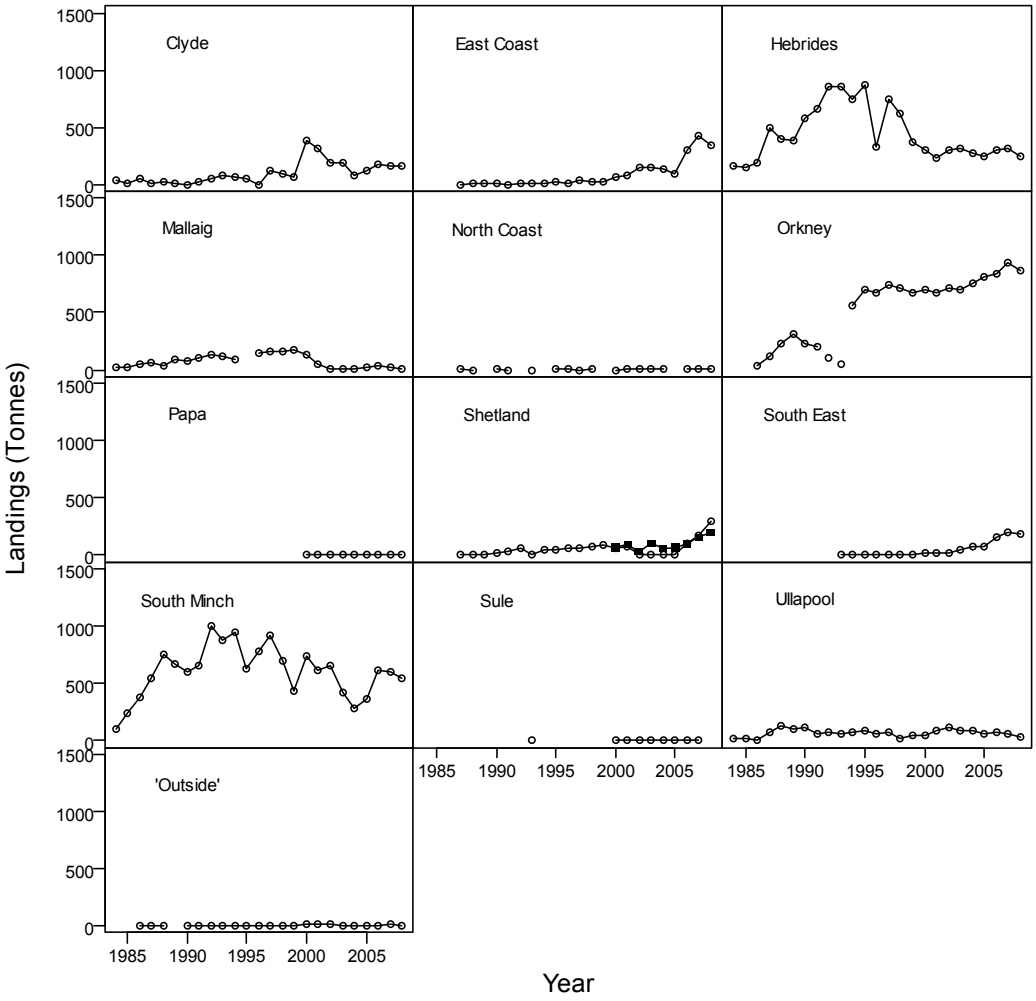

Figure 5: Annual velvet crab landings (tonnes) into Scotland by assessment area 1984-2008. Data from the Fisheries Management Database; Data in black filled squares for Shetland (2000-2008) are from Shetland Shellfish Management Organisation logbooks (supplied by NAFC Marine Centre with permission from the Shetland Shellfish Management Organisation). 'Outside' relates to velvet crab landed outside MSS crab and lobster assessment areas; see Figure 1 for area locations.

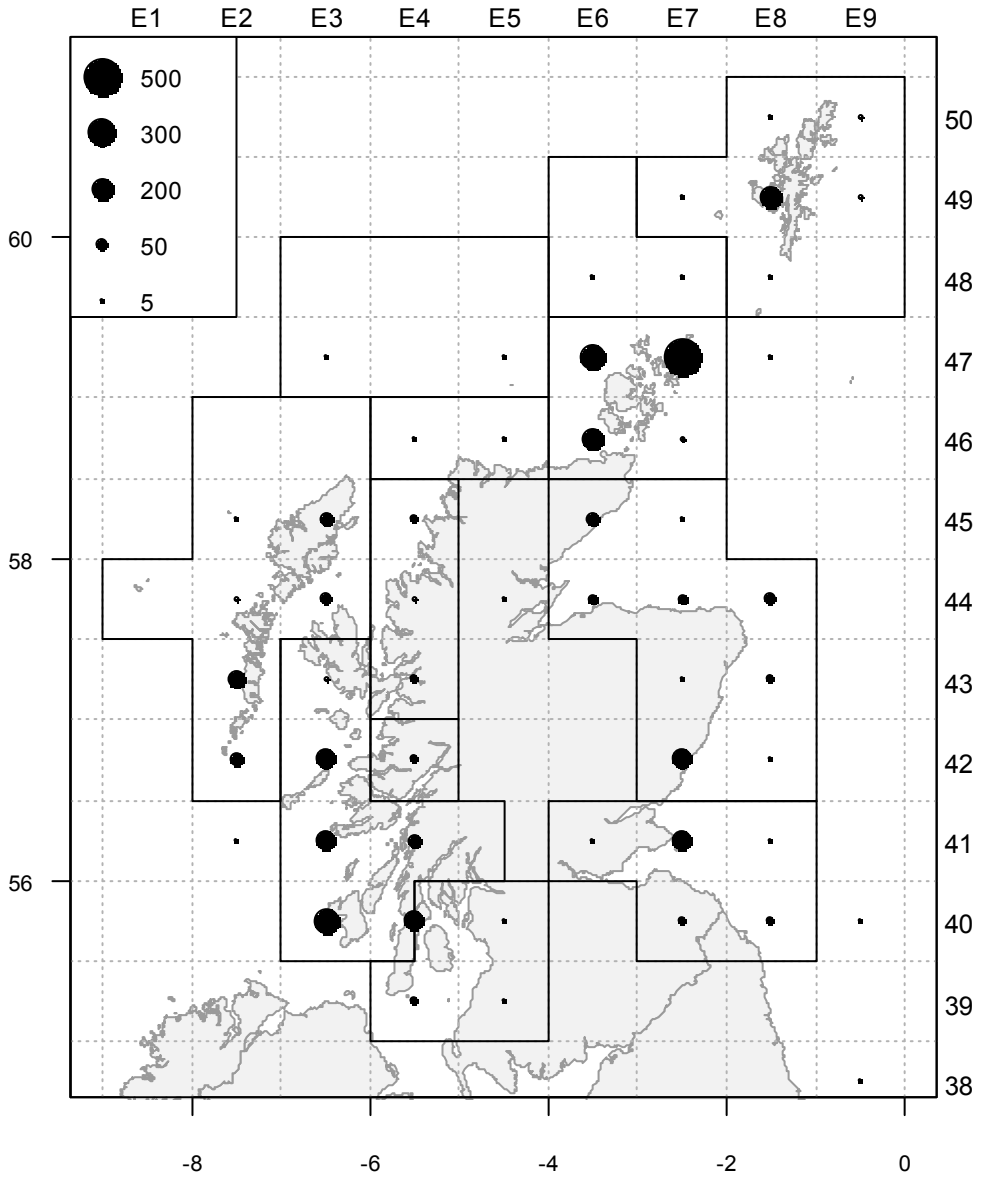

Figure 6: Average velvet crab landings (tonnes) by statistical rectangle between 2006 and 2008. Filled circles represent landings into Scotland. Data are from Fisheries Management Database.

Lobster

The total tonnage of lobster landed in Scotland has always been much less than that of crabs. However, lobster landings have increased substantially in recent years, from 415 tonnes in 2001 to about 1,000 tonnes in 2008. The average price per kilogram of lobster is much higher than that of crab, and the lobster fishery was more important than the velvet and brown crab fisheries, in terms of total value from 1980 to 1993 (Figure 2b). Average prices of lobster have been stable at around £2 per kilogram in the last four years (Figure 2c).

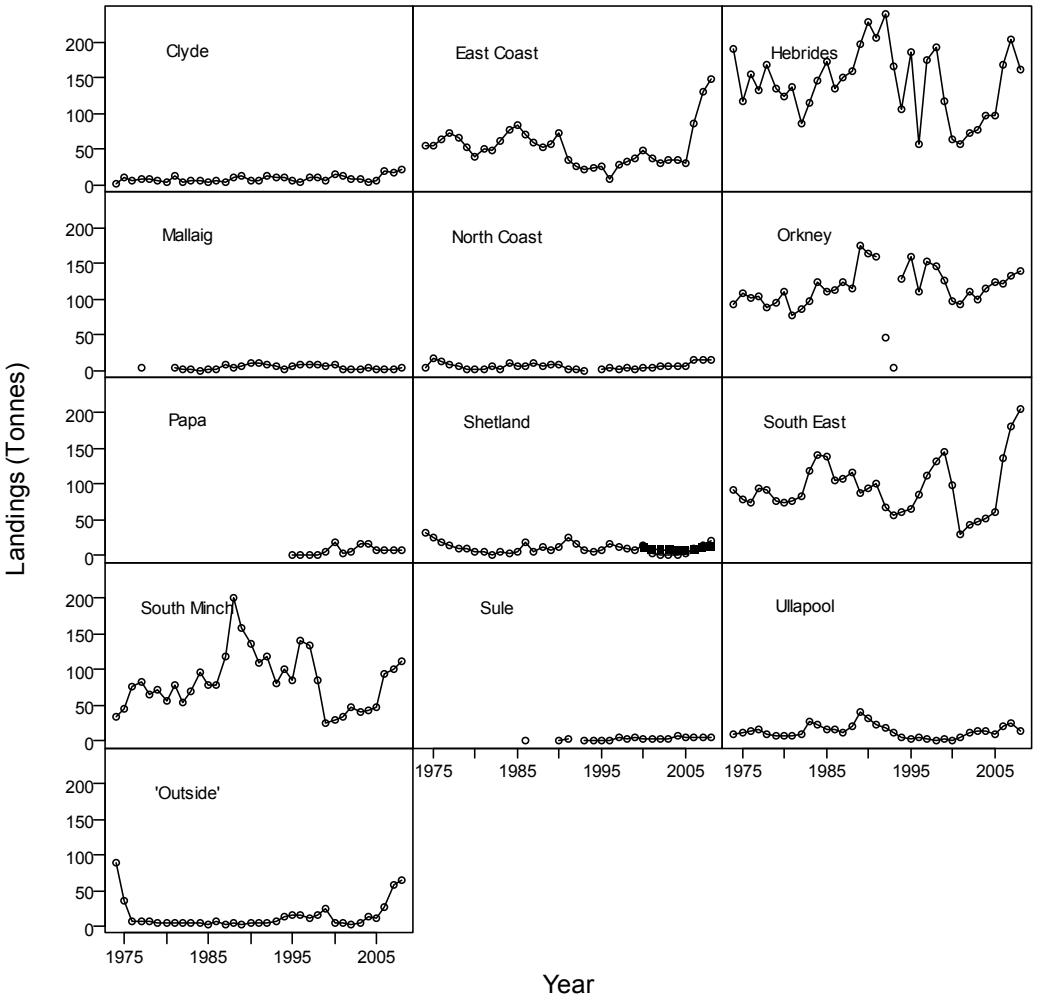

Figure 7: Annual lobster landings (tonnes) into Scotland by assessment area 1974-2008. Data from the Fisheries Management Database; Data in black filled squares for Shetland (2000-2008) are from Shetland Shellfish Management Organisation logbooks (supplied by NAFC Marine Centre with permission from the Shetland Shellfish Management Organisation). 'Outside' relates to lobster landed outside MSS crab and lobster assessment areas; see Figure 1 for area locations.

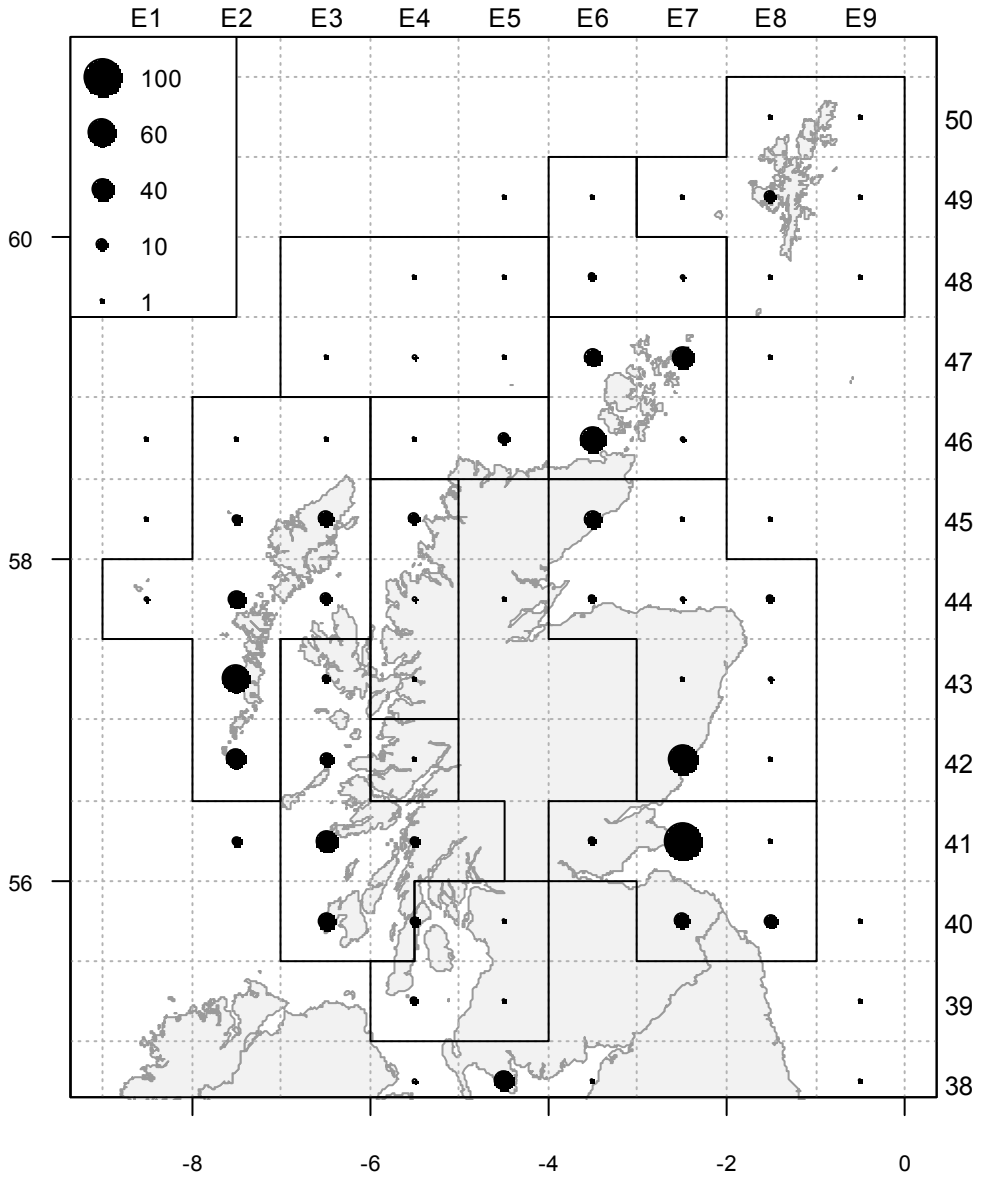

Figure 8: Average lobster landings (tonnes) by statistical rectangle between 2006 and 2008. Filled circles represent landings into Scotland. Data are from Fisheries Management Database.

Figure 8 shows the spatial distribution of lobster landings around Scotland averaged over 2006-2008. Over the past thirty years the majority of landings of lobster in Scotland have been from the Hebrides, Orkney, South East and South Minch areas (Figure 7). The period between 1999 and 2004 was characterised by lower landings from all of these areas. This decline can be related to an increase in minimum landing size to 87 mm in 1999; the effect on landings being evident for the next five years. Landings from 2006 to 2008 appeared comparable with earlier levels although prior to the introduction of buyers and sellers regulations, landings may have been underreported. It is therefore unclear whether the increase in landings is attributable to the fishery re-stabilising after the increase in MLS or whether it is due to improved reporting under buyers and sellers legislation.

Table 4

The Scottish Crab and Lobster fisheries by region; Percentage of total landings into Scotland of brown crab, velvet crab and lobster 2006–2008. Data are from the Fisheries Management Database.

Species	Year	Clyde	East Coast	Hebrides	Mallaig	North Coast	Orkney	Papa Bank	Shetland	South East	South Minch	Sule	Ullapool
Brown crab	2006	1.9	8.1	22.1	0.1	4.2	14.2	8.1	6.2	2.7	12.8	16.1	3.5
	2007	2.1	7.5	19.9	0.6	4.4	13.2	6.8	4.4	2.4	18.3	17.2	3.2
	2008	2.3	9.4	18.8	0.3	3.8	12.8	8.2	6.1	3.5	12.3	19.8	2.6
Velvet crab	2006	6.8	11.5	11.3	1.3	0.3	32.5	0.2	3.9	5.9	23.7	0	2.7
	2007	5.6	14.8	11.0	0.7	0.2	32.4	0.1	5.7	6.8	20.6	0	2.1
	2008	6.1	13.0	9.2	0.1	0.1	32.6	0.1	10.9	6.8	20.2	0	0.9
Lobster	2006	2.7	12.7	24.6	0.1	2.3	17.8	1.1	1.4	19.9	13.8	0.8	2.9
	2007	2.0	15.6	24.5	0.1	1.7	15.9	1.0	1.7	21.7	12.2	0.6	2.9
	2008	2.6	17.4	19.0	0.4	1.8	16.3	0.8	2.3	24.1	13.1	0.6	1.6

Landings from Outside Scottish Assessment Areas

Between 2006 and 2008, the majority of the crab and lobster landings taken by Scottish boats were from within the current creel assessment areas. However, a small proportion came from grounds outside these areas, particularly for brown crab (Figure 4). Landings of brown crab taken by Irish boats between 2006 and 2008 were mainly concentrated in the southwest of Scotland just outside the South Minch area (statistical rectangles 40E2, 39E2 and 39E9) although some were also taken in the offshore areas of Sule, Papa and the Outer Hebrides. For velvet crab, landings from outside the assessment areas were low for this period (Figure 6) while for lobster, moderate landings were observed just outside the Clyde area in statistical rectangle 38E5 (Figure 8). Currently, these data are not included in the assessments but may need to be in the future, particularly when a high volume of landings is recorded from a single statistical rectangle. An additional issue relates to waters which are shared with England and Ireland. On the east coast, the Scottish assessment area (South East) extends beyond the Scottish border while on the west coast the assessment area (Clyde) stops short of the border. There are currently no agreed procedures for assessing “cross-border” stocks.

3.2 Regional Assessments

3.2.1 Clyde

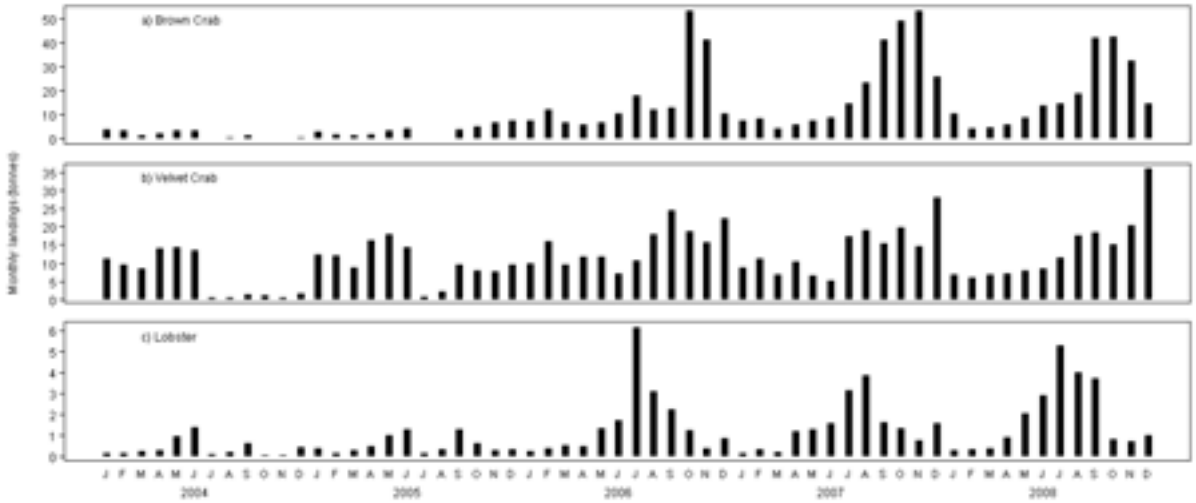

Figure 9: Monthly landings of brown crab, velvet crab and lobster for the Clyde assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

The Clyde area supports a small crab and lobster creel fishery. Landings of brown crab and lobster accounted for less than 3% of the national total between 2006 and 2008, with velvet crab landings typically around 6% of the Scottish total over this period. Boats land into the ports of Troon, Cambeltown and Tarbert.

Brown Crab

There has been a marked increase in reported brown crab landings in the Clyde area in the last three years which may be related to the introduction of the buyers and sellers legislation from 2006. There are marked seasonal patterns in the landings in these years, with larger landings occurring in the last quarter (Figure 9). No clear indications of strong year classes are apparent in the length frequency data shown in Figure 10. However, this figure also indicates that sampling has been sporadic. Average size of the top 20% of individuals landed show an increase in size from around 160 mm in the early 90's to around 180 mm in 2008 (Figure 11). This is indicative of an increase in the proportion of very large individuals in the stock, then it could potentially suggest decreased fishing mortality. However, this trend could also be an artifact of changes in fishing patterns or discard practices, and without further fishery information it is difficult to conclude which is more likely. Figure 12 shows the brown crab length frequency distribution (2007-2008) for this area where the average size of females (161.8 mm) was greater than that of males (153.6 mm). LCA indicates that fishing mortality is above F_{MAX} for both males and females and a reduction in effort would increase the yield-per-recruit by a few percent of the current level (Figure 13).

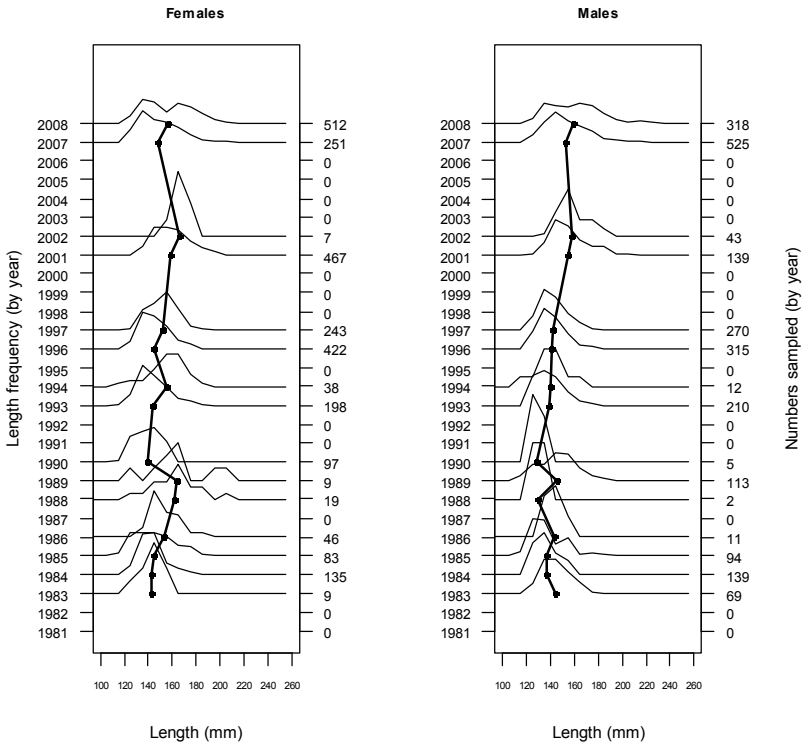

Figure 10: Time series of length frequency for brown crab in the Clyde assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

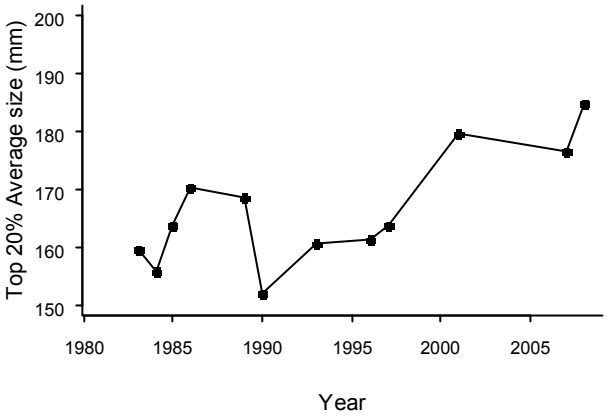

Figure 11: Brown crab average size of the top 20% individuals sorted by size in the Clyde assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

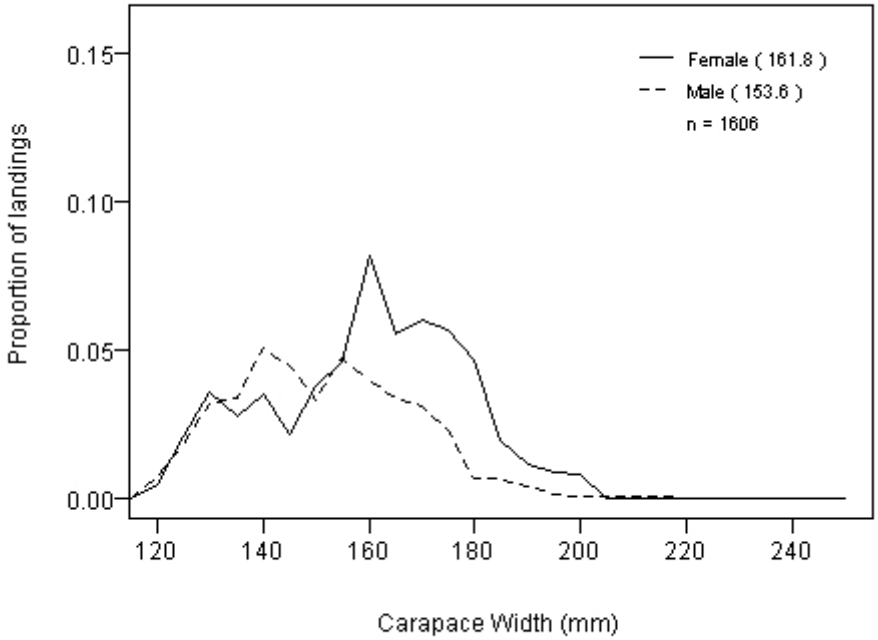

Figure 12: Brown crab carapace width (mm) frequency histogram for the Clyde assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2007-2008 (no sample data for 2006). The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

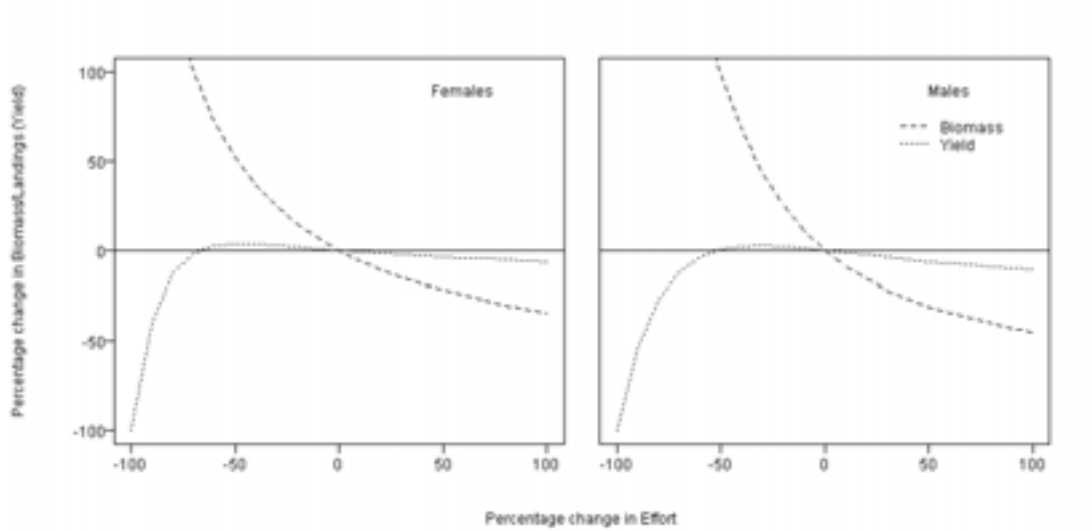

Figure 13: Biomass and Yield-per-recruit predictions for given changes from current effort for brown crab in the Clyde assessment area, data from 2007-2008 (no sample data for 2006). See Figure 1 for area locations.

Velvet Crab

Monthly reported landings of velvet crab from the Clyde have been consistently above 10 tonnes except for a period in the latter half of 2004 and July and August in 2005. Although there is not a strong seasonal pattern in the landings from this area, since 2006, landings have typically been greatest in the last quarter of the year (Figure 9). Figure 14 shows the length frequency distribution (LFD) time series for velvet crab in the Clyde, where sampling in the last years has increased compared to the late 1990's although is still relatively poor. The stability in the sampled landings LFDs may be indicative of stability in the size structure of the exploited population due to fairly stable recruitment and fishing mortality (although this may not be the case if fishing practices have changed over time). No marked differences were apparent when recent average sizes of the largest 20% individuals were compared to those from 15 years ago (Figure 15) although there are large inter-annual variations which are likely to be due to the low numbers of sampled individuals. According to the market sampling data, landings of male velvet crabs in the Clyde exceed those of females, although the mean sizes are similar (Figure 16). However, samples for this species were only taken in the first half of the year in 2007 and 2008. Although data are limited (862 length frequency measurements), LCAs were carried out for the area. The yield-per-recruit prediction curves indicate that males are being exploited above F_{MAX}. A 70% reduction in effort would result in an increase in yield- per-recruit of 12% (Figure 17). Females are also being fished above F_{MAX}. Velvet crabs landed from the Clyde are generally smaller than in other assessment areas but the growth parameters assumed in this assessment are the same as those applied to the other areas. Such an assumption, if incorrect, would lead to the conclusion (from LCA) that the stocks are more heavily fished than they actually are.

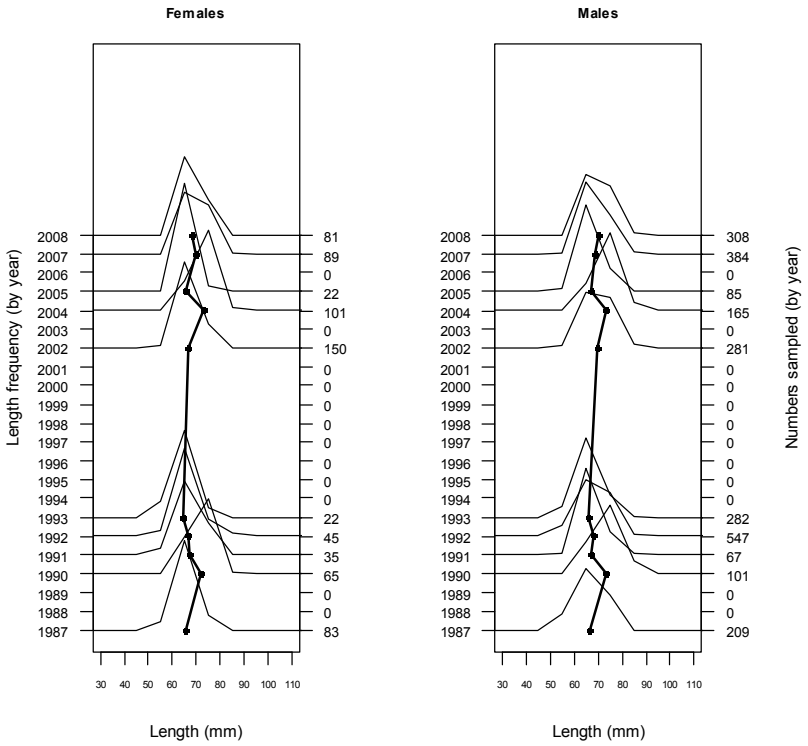

Figure 14: Time series of length frequency for velvet crab in the Clyde assessment area between 1987 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

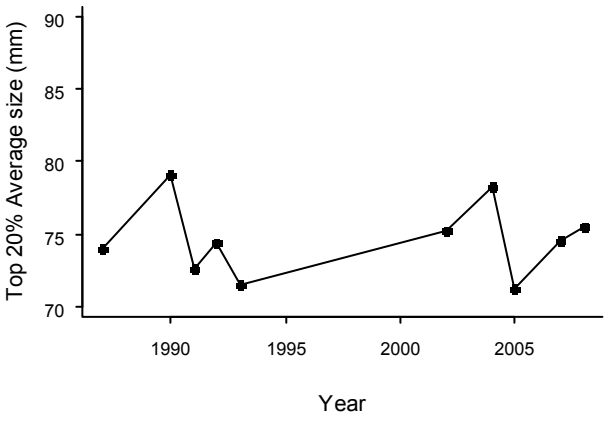

Figure 15: Velvet crab average size of the top 20% individuals sorted by size in the Clyde assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

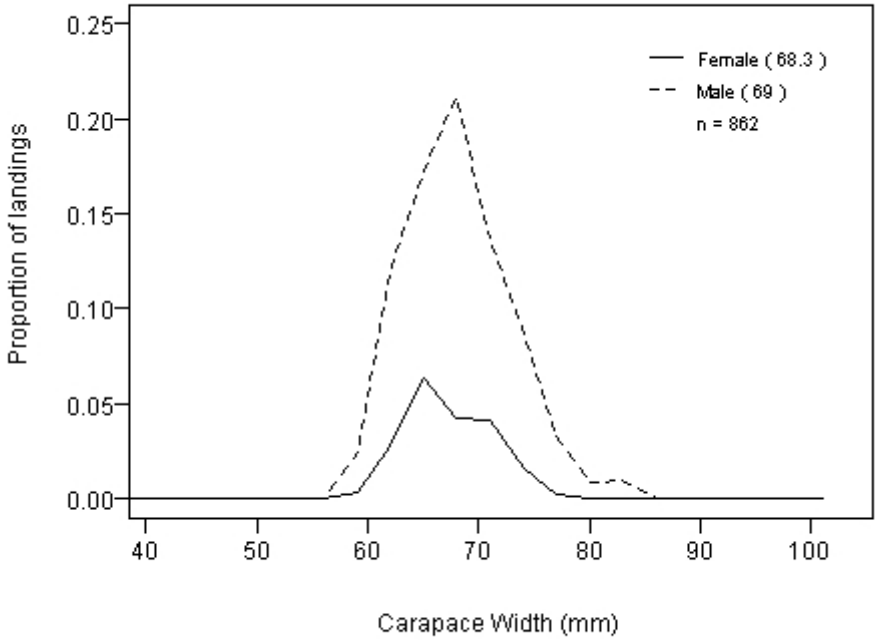

Figure 16: Velvet crab carapace width (mm) frequency histogram for the Clyde assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 3 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

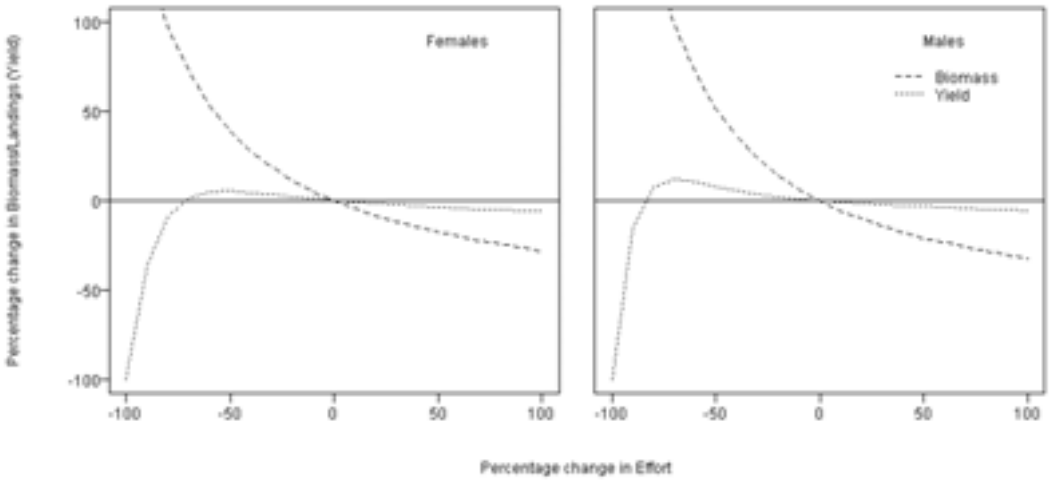

Figure 17: Biomass and Yield-per-recruit predictions for given changes from current effort for velvet crab in the Clyde assessment area, data from 2006-2008. See Figure **1** for area locations.

Lobster

The lobster fishery in the Clyde made up just over 2% of the total Scottish landings during 2006-2008 (Table 4). The landings follow a similar seasonal pattern each year with the largest landings typically occurring in July, August and September (Figure 9). No strong year classes are apparent in LFDs (Figure 18), although sampling levels are low and trends are difficult to detect as no sampling took place between 2001 and 2005 (Figure 18). Recent average sizes (2006-2008) of the largest 20% individuals fall within the range of values previously observed. However, these are highly variable, possibly due to low sample sizes (Figure 19). Lobsters sampled from Clyde are among the smallest in Scotland with an average size of 97.5 mm CL (Figure 20). LCA yield-per-recruit curves indicate that both male and female lobster stocks in the Clyde are being fished above F_{MAX} (Figure 21). The yield-per-recruit of males would benefit from a reduction in fishing effort: a 50% reduction corresponds to an 11% increase in the yield-per-recruit.

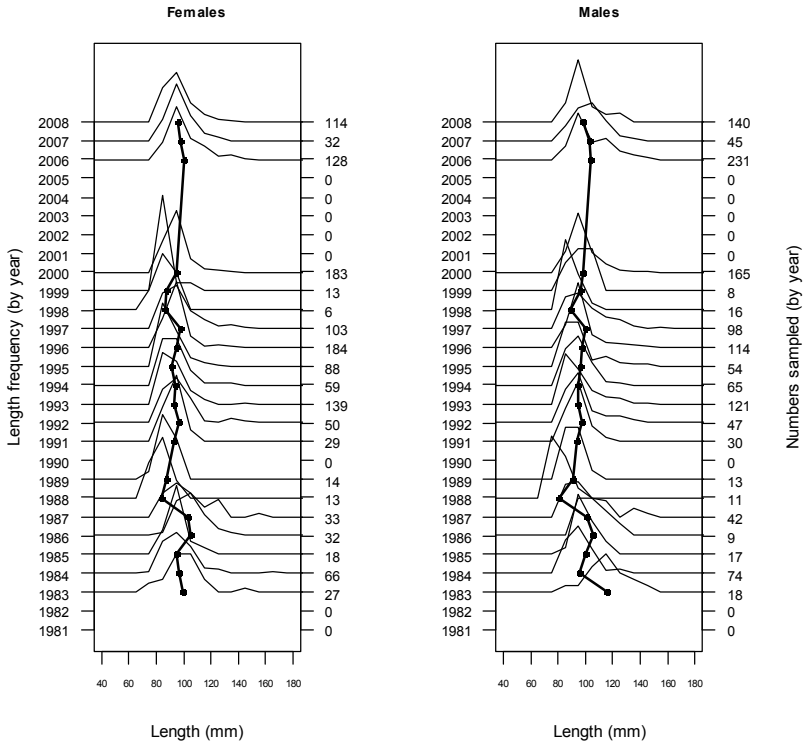

Figure 18: Time series of length frequency for lobster in the Clyde assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

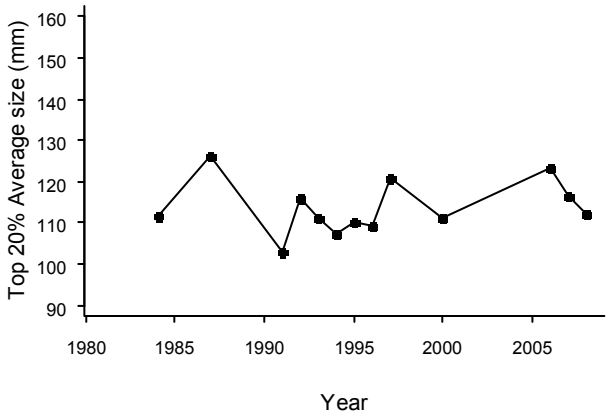

Figure 19: Lobster average size of the top 20% individuals sorted by size in the Clyde assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

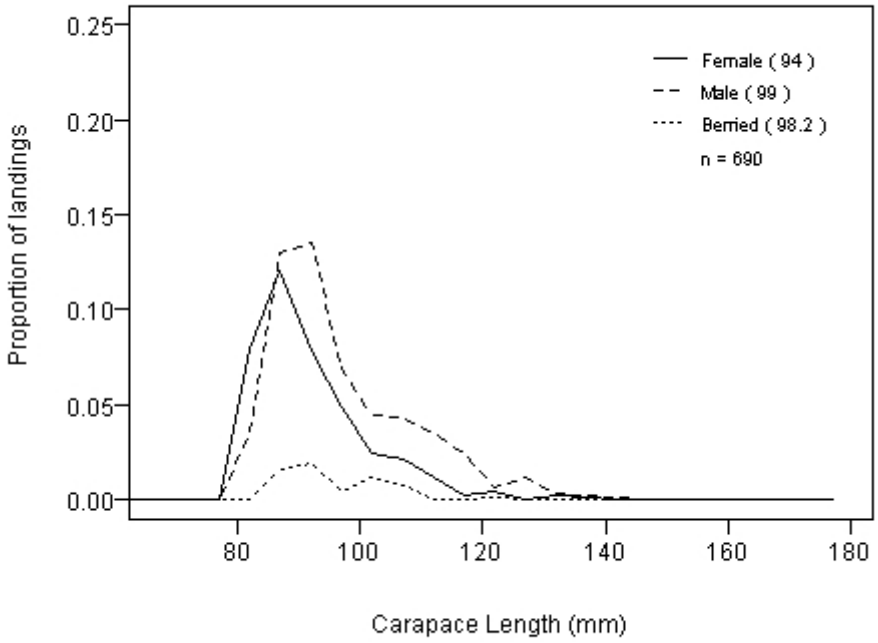

Figure 20: Lobster carapace length (mm) frequency histogram for the Clyde assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

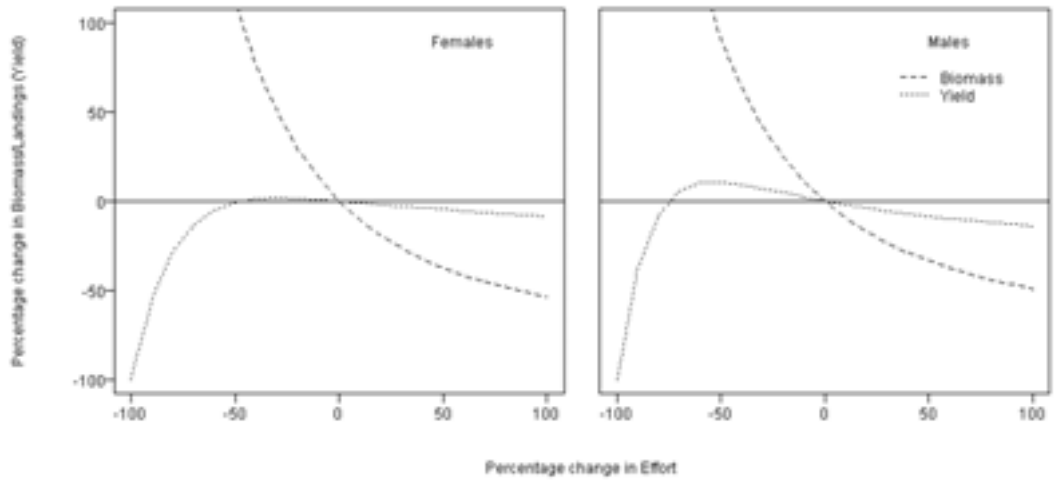

Figure 21: Biomass and Yield-per-recruit predictions for given changes from current effort for lobster in the Clyde assessment area, data from 2006-2008. See Figure 1 for area locations.

3.2.2 East Coast

The East Coast is one of the largest crab and lobster assessment areas. It covers the majority of the east coast of Scotland including the ports of Arbroath, Johnshaven, Buckie and Helmsdale as well as other ports in the Moray Firth (Figure 1). The majority of vessels that operate in this region are small (<10 m) day vessels and more vessels tend to participate in the fishery during the summer than in the winter.

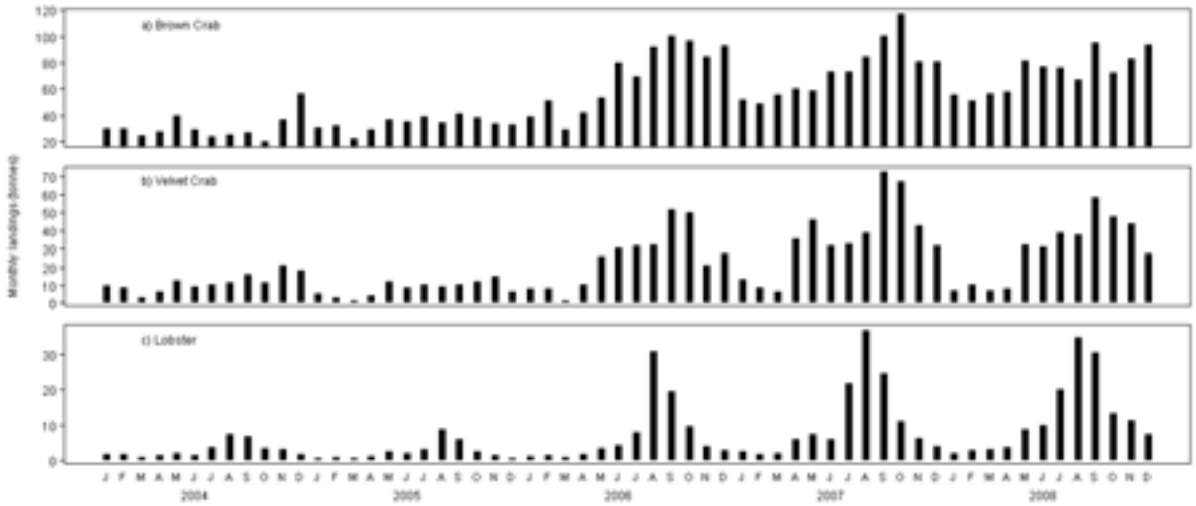

Figure 22: Monthly landings of brown crab, velvet crab and lobster for the East Coast assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

The brown crab landed from the East Coast made up between 7.5 and 9.4% of the total brown crab landed in Scotland between 2006 and 2008. There is no marked seasonal pattern, but reported landings are slightly higher in the second half of the year in most years (Figure 22). The long term LFDs and the mean size of the largest 20% of individuals are shown in Figure 23 and Figure 24, respectively. In some years (e.g. 2003 and 2005) higher proportions of smaller individuals were evident in the samples which may be indicative of increases in recruitment. Recent mean sizes of the largest 20% of individuals in the landings are lower than those from samples from the early 1990s but are greater than those at the start of the time series. This could reflect changes in fishing mortality (a decrease followed by a recent increase), but could also be due to changes in fishing patterns or discard practices. In general, historical sampling levels in this area were relatively good. Sampling levels fall in the mid 2000s which may account for some of the more variable mean sizes seen during these years. Males predominated in the sampled landings (60%) and were on average smaller than the females (Figure 25). Yield-per-recruit predictions from the LCA indicate that male brown crab in the East Coast area are overexploited in terms of growth overfishing and that a reduction in fishing effort would increase yield-per-recruit. Females are being fished at around F_{MAX} (Figure 26).

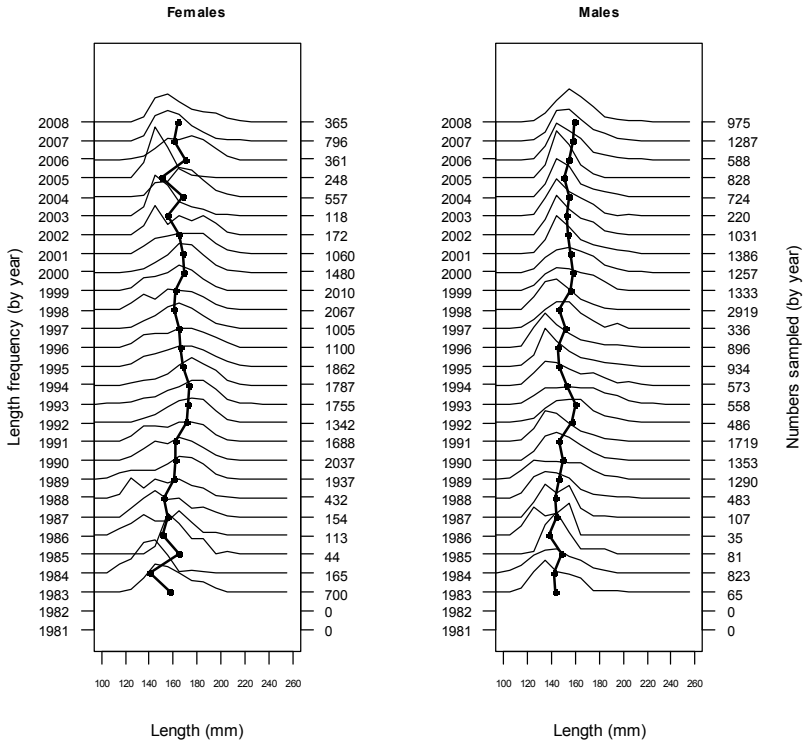

Figure 23: Time series of length frequency for brown crab in the East Coast assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

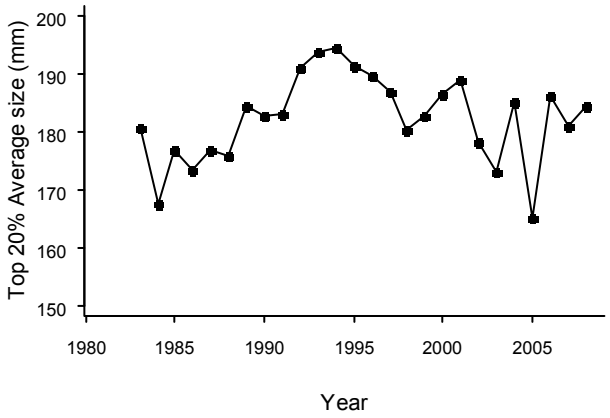

Figure 24: Brown crab average size of the top 20% individuals sorted by size in the East Coast assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

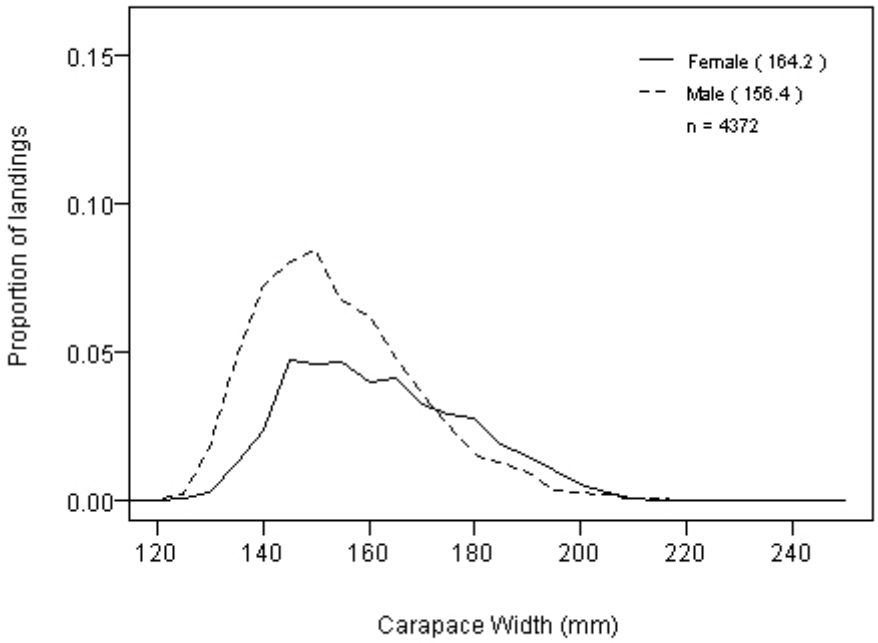

Figure 25: Brown crab carapace width (mm) frequency histogram for the East Coast assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

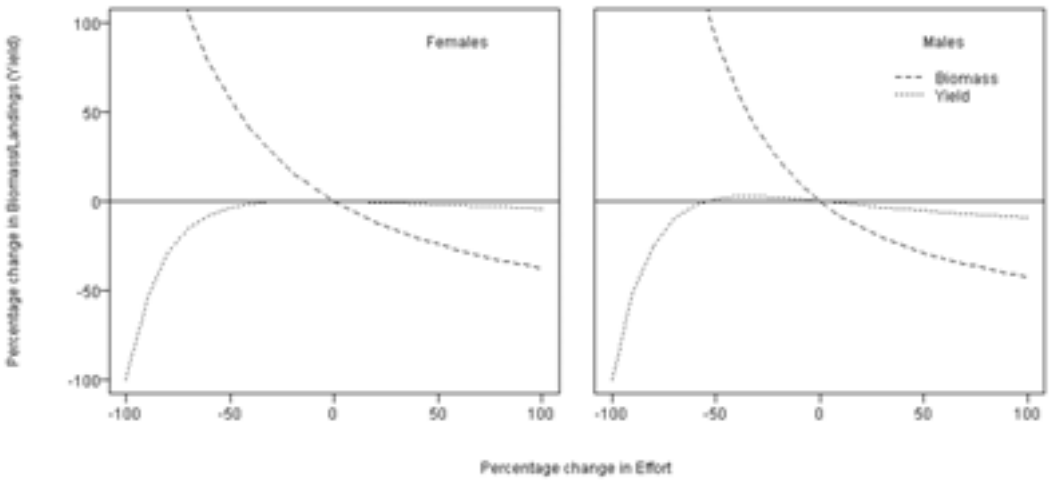

Figure 26: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the East Coast assessment area, data from 2006-2008. See Figure 1 for area locations.

Velvet Crab

Velvet crab are caught all year round in the East Coast area with an increase in the landed weight evident in the summer months (Figure 22). Fishermen have reported an increase in the abundance of velvet crab in the past few years. Initially, velvet crab were only a by-catch in the brown crab fishery, but a steady fishery has developed. Catches in the area are collected once a week by vivier lorry for transportation to the continent. The long term time series of LFDs is shown in Figure 27. No clear year class signals are apparent in the data. The average size of the largest individuals varies (but unsystematically) between 74 mm and 84 mm (Figure 28). It is difficult to pick out long term trends in the size frequency of this stock as the data in many years is inadequate (very low or zero sample size). Length frequency data from sampled landings (2007-2008) suggests ca. 81% of the velvet crabs landed were males (Figure 29). LCA indicates that both male and female stocks are being fished close to F_{MAX} (Figure 30).

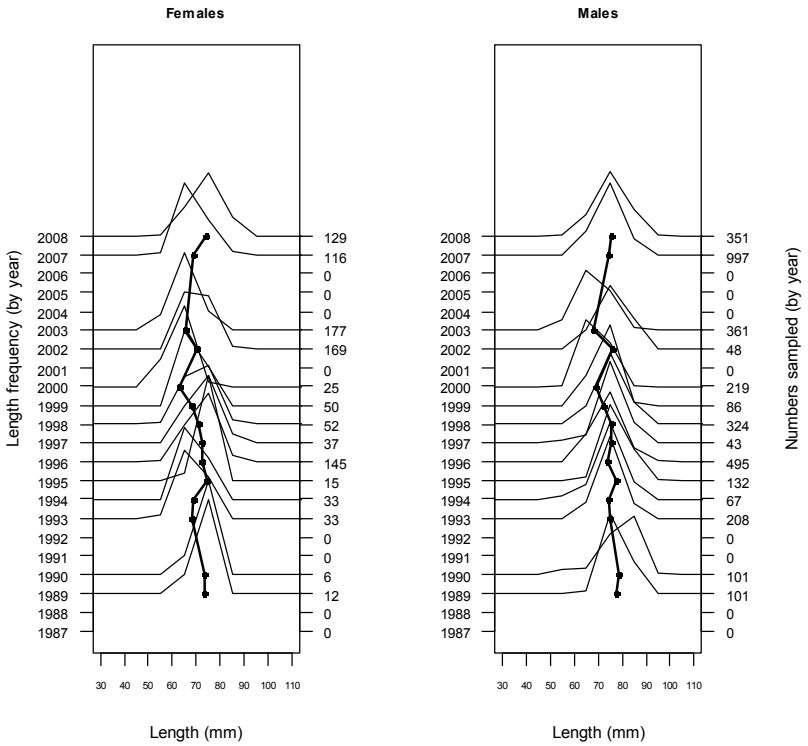

Figure 27: Time series of length frequency for velvet crab in the East Coast assessment area between 1987 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

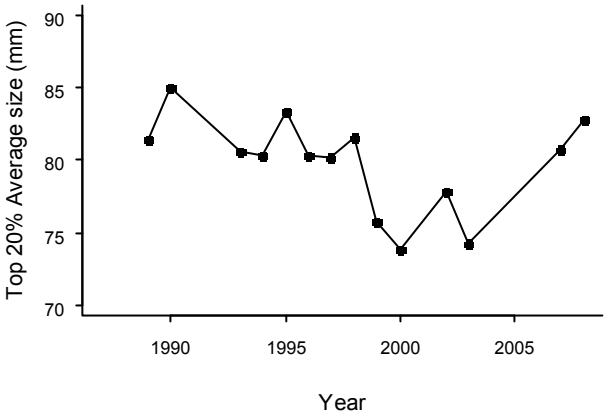

Figure 28: Velvet crab average size of the top 20% individuals sorted by size in the East Coast assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

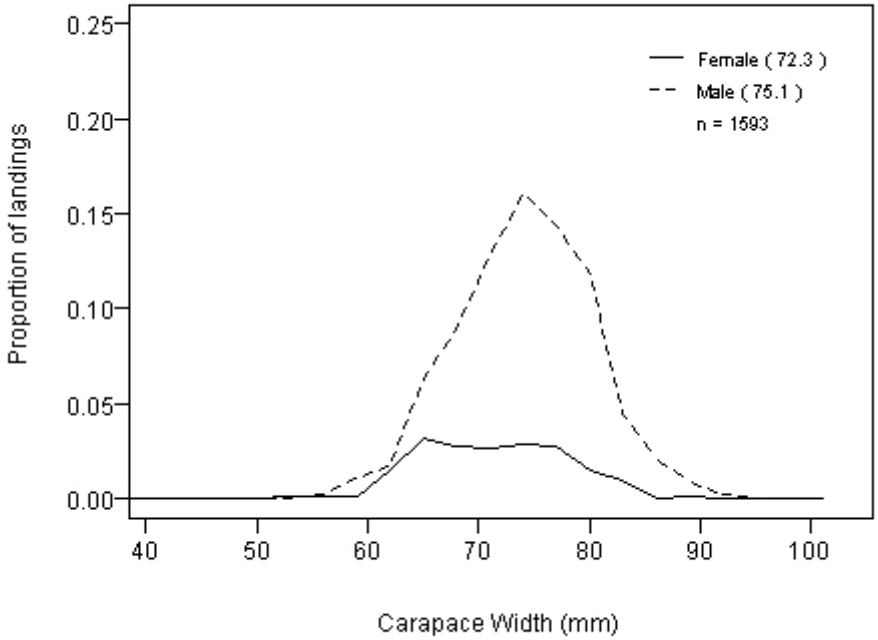

Figure 29: Velvet crab carapace width (mm) frequency histogram for the East Coast assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 3 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

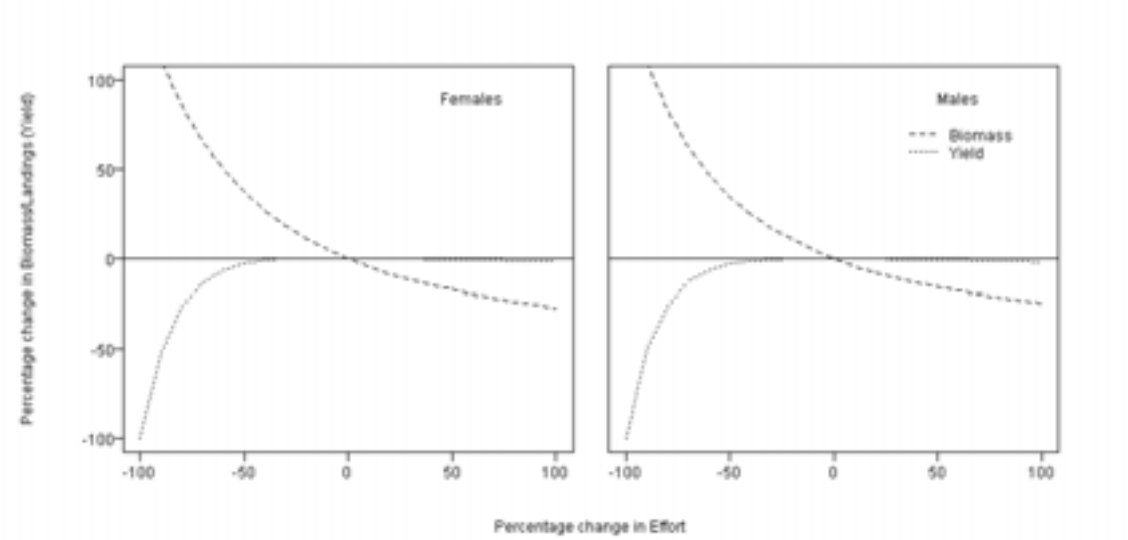

Figure 30: Biomass and Yield-per-recruit predictions for given changes from current effort for velvet crab in the East Coast assessment area, data from 2006-2008. See Figure 1 for area locations.

Lobster

The lobster landings from the East Coast averaged around 15% of the Scottish total between 2006 and 2008 (Table 4). The majority are landed in the summer months with a significant seasonal peak in August and September (Figure 22). The long term LFDs and the mean size of the largest 20% individuals are shown in Figure 31 and Figure 32, respectively. The sampled LFDs appear relatively stable over the sampling period and there is no systematic change in the mean size of the largest individuals (although the low sample levels between 2001 and 2006 make recent trends difficult to detect). Assuming that fishing and discard practices have not changed significantly over this period, such a trend could potentially be an indication that fishing has remained relatively stable over this period. Market sampling data indicate that approximately equal numbers of male and female lobsters were landed during this period but the mean carapace length of the male lobsters was slightly greater than the non-berried females (Figure 33). LCA indicates that both males and females are being fished above F_{MAX} (Figure 34). In the case of males, a 50% reduction in fishing effort would result in increasing the yield-per-recruit by 11%.

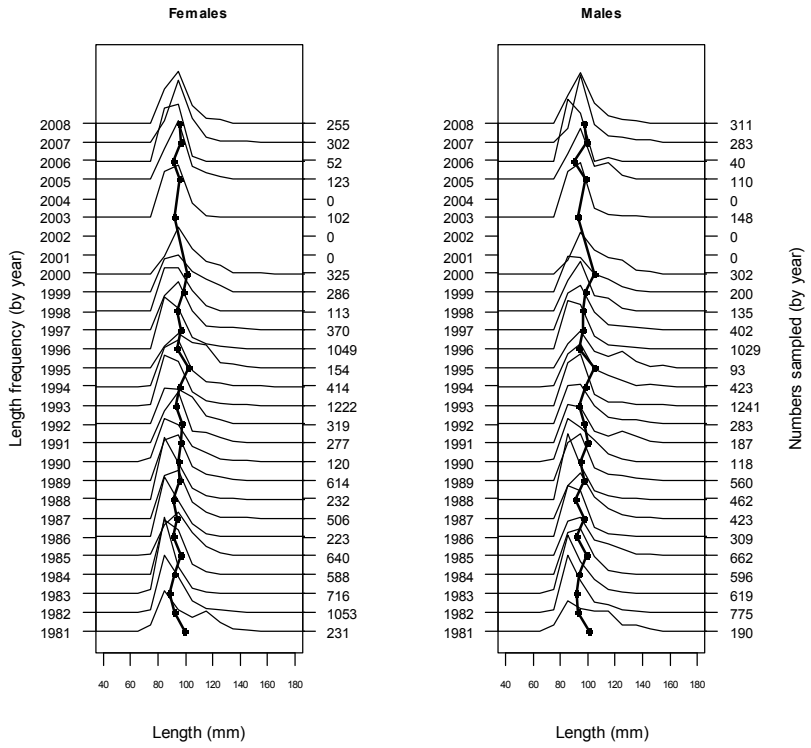

Figure 31: Time series of length frequency for lobster in the East Coast assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

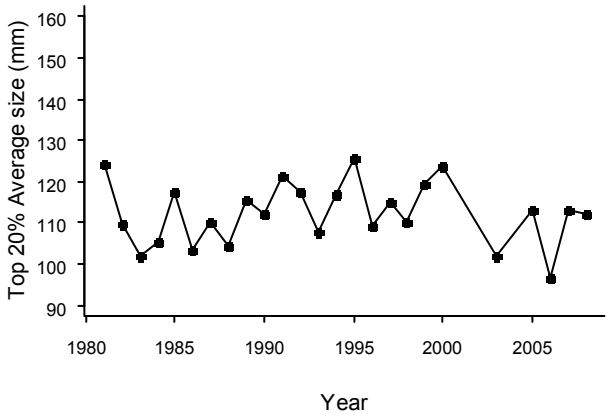

Figure 32: Lobster average size of the top 20 % individuals sorted by size in the East Coast assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

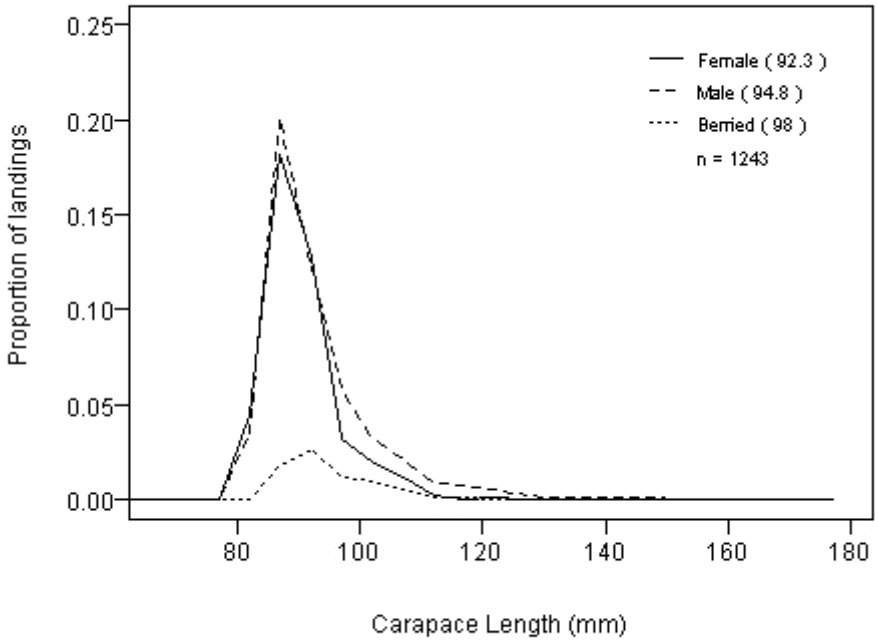

Figure 33: Lobster carapace length (mm) frequency histogram for the East Coast assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

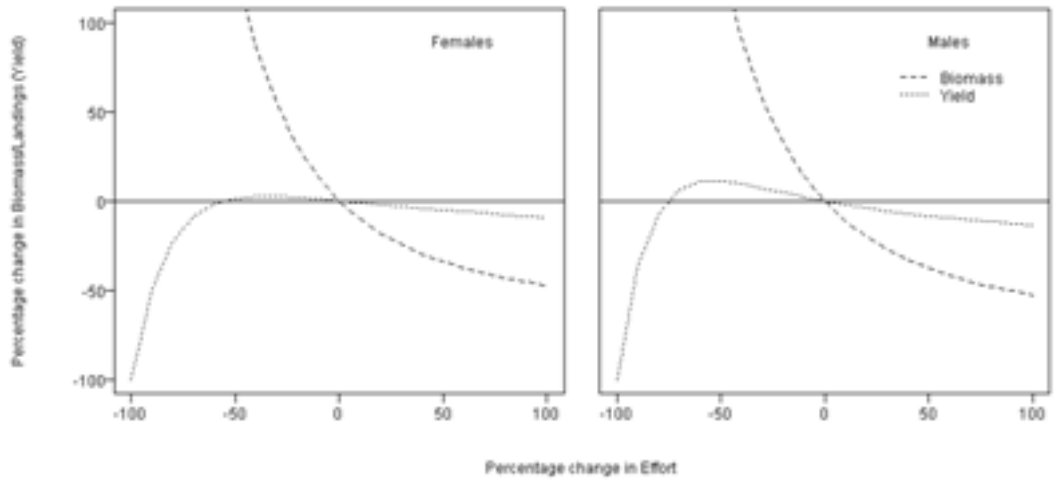

Figure 34: Biomass and Yield-per-recruit predictions for given changes from current effort for lobster in the East Coast assessment area, data from 2006-2008. See Figure 1 for area locations.

3.2.3 Hebrides

Traditionally the Hebrides has been a successful and important lobster and crab fishing area. The islands of Uist, Lewis, Harris, Benbecula and Barra all have small fishing communities and small inshore creel fleets which operate daily.

As in other areas, the seasonal landings show an increase during the summer months but high landings are also recorded in December, especially for velvet crab (Figure 35). This seasonal landing pattern was less obvious in the brown crab landings during these years whilst the lobster landings were highest in June, July and August.

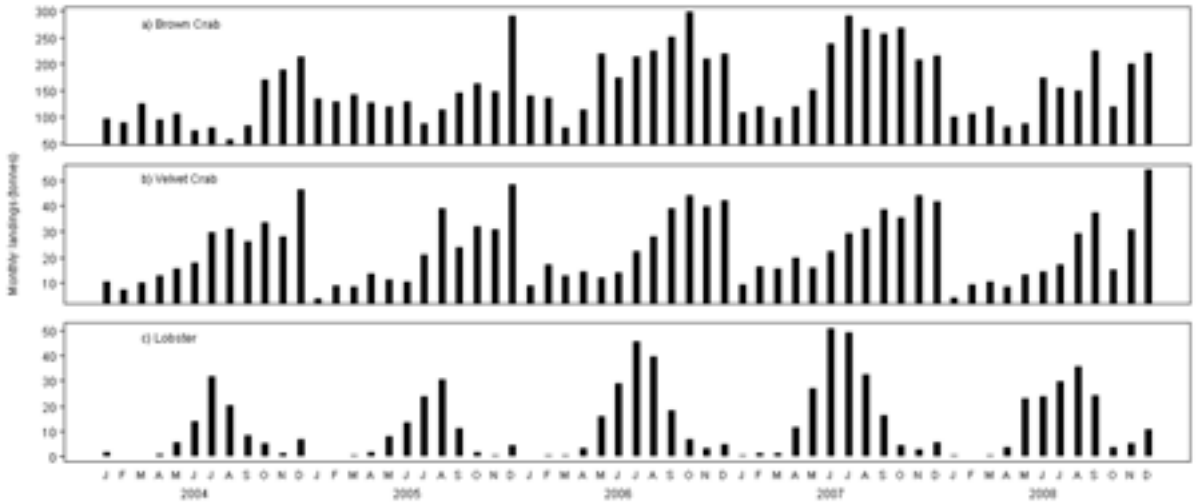

Figure 35: Monthly landings of brown crab, velvet crab and lobster for the Hebrides assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

The brown crab landed from the Hebrides assessment area represented approximately 20% of the total Scottish landings between 2006 and 2008 (Table 4). There was a substantial reduction in reported landings from this area in 2008: 1,700 tonnes compared to 2,300 tonnes in 2007. The sampled long term landings LFDs (Figure 36) show fewer small individuals in recent years, which may be indicative of lower recent recruitment, but could also be due to changes in discard practices (small individuals being caught but not landed). The average size of largest individuals (sexes combined) shows no sign of decline over the 25 year time period (Figure 37). If fishing and discard practices have remained relatively consistent over time then this could indicate that fishing mortality has remained relatively stable. According to the market sampling data, 77% of the brown crabs landed were female and the mean size of sampled females was larger than the male crabs (Figure 38). Over the period considered in this report, sampling in the Hebrides has occurred throughout the year and therefore the sex ratio is not likely to be biased because of seasonality of sampling. LCA predictions indicate that both male and female brown crab in the Hebrides are being fished close to F_{MAX}, and that any increase in effort would result in a decrease in overall yield-per-recruit (Figure 39).

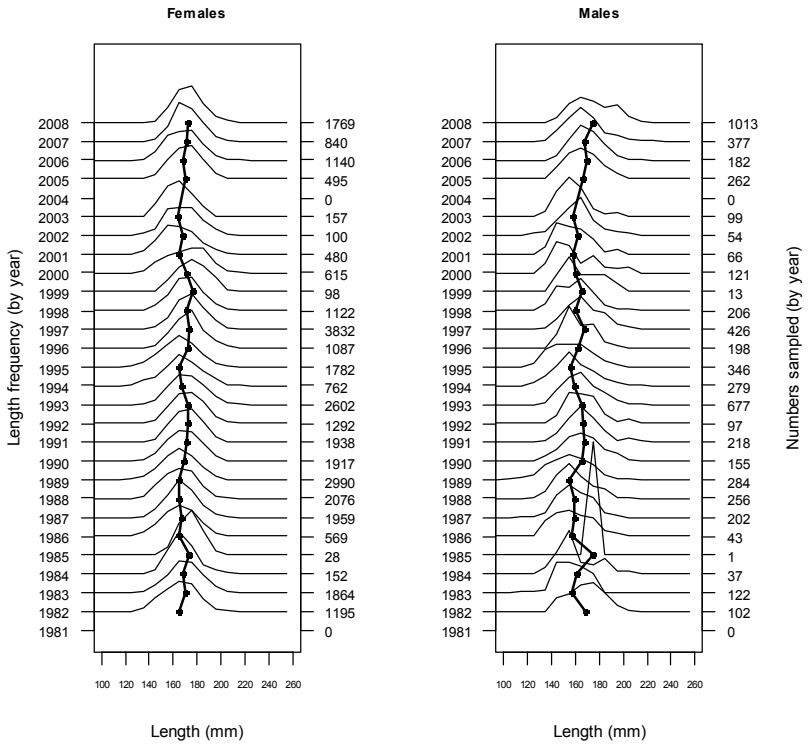

Figure 36: Time series of length frequency for brown crab in the Hebrides assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

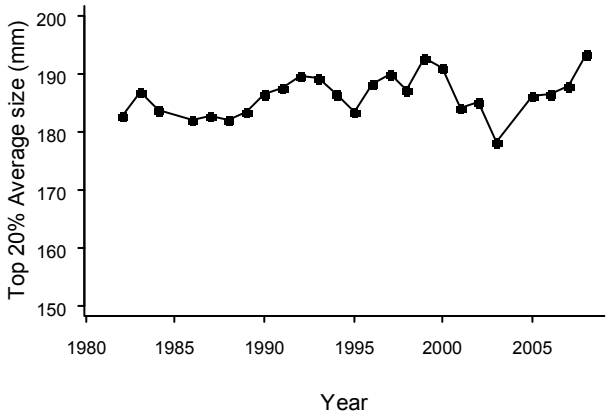

Figure 37: Brown crab average size of the top 20% individuals sorted by size in the Hebrides assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

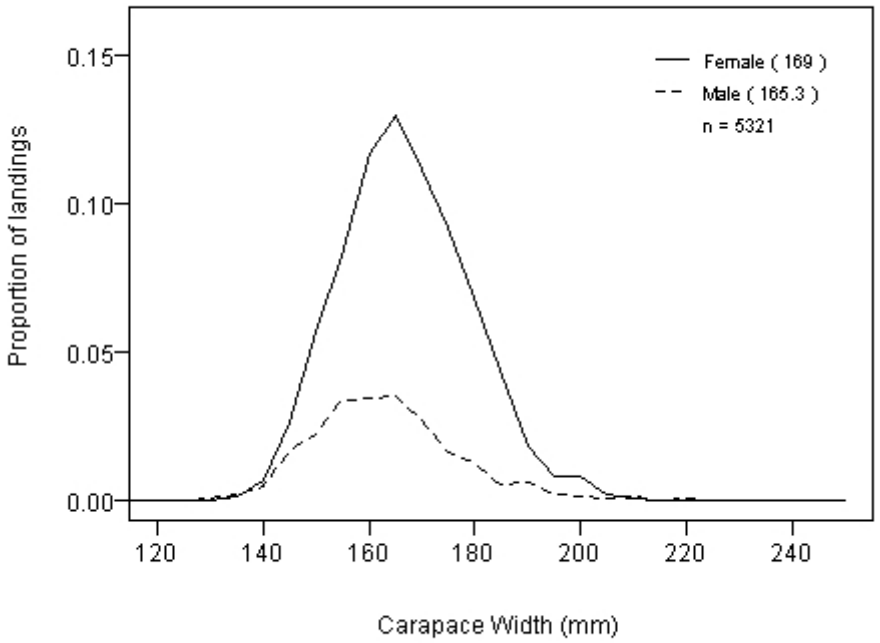

Figure 38: Brown crab carapace width (mm) frequency histogram for the Hebrides assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

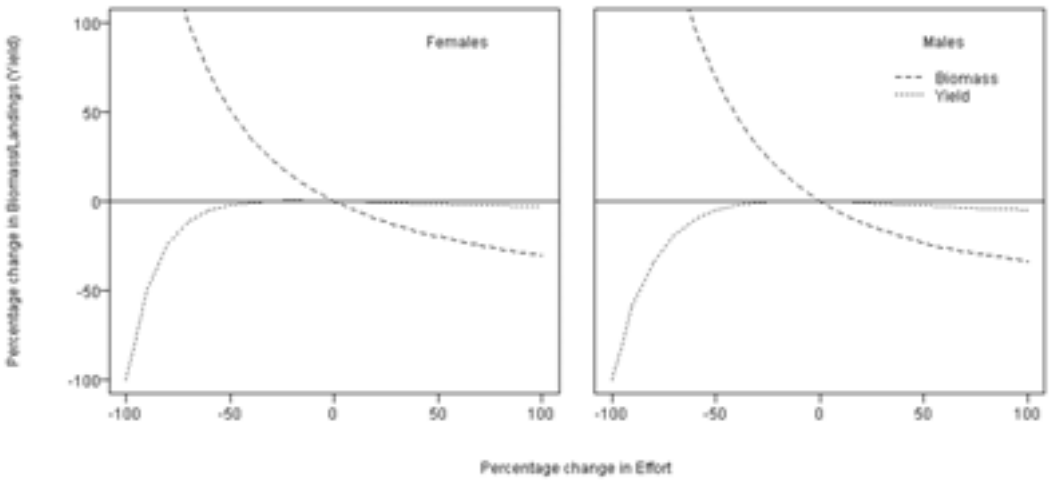

Figure 39: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the Hebrides assessment area, data from 2006-2008. See Figure 1 for area locations.

Velvet Crab

Although there is no fishery directed solely at velvet crab, the Hebrides had the fourth largest Scottish landings by weight between 2006 and 2008 (about 10% of the total). Landings tend to be greater in the second half of the year (Figure 35). Long term LFDs appear stable in the most recent years (Figure 40) but the average size of largest individuals in the sampled landings has increased from below 80 mm to almost 85 mm over the last ten years (Figure 41). If the landings LFDs are representative of the population size structure then this may indicate that fishing mortality may have declined over this period. The size structure of the sampled landings is similar for both sexes, although there appear to be more males (67%) in the landings than females (Figure 42). LCA indicates both male and female stocks are being fished close to F_{MAX} (Figure 43).

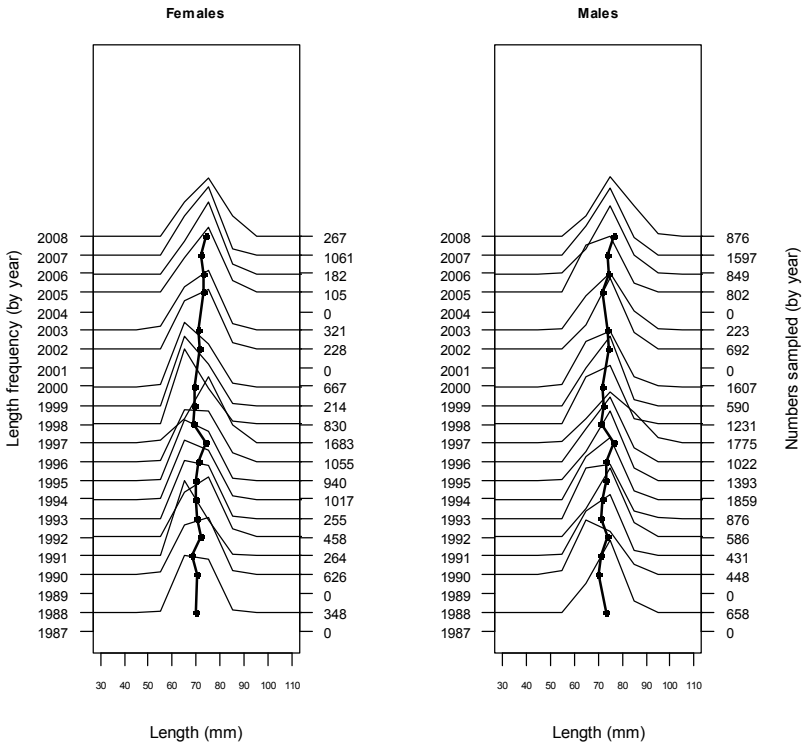

Figure 40: Time series of length frequency for velvet crab in the Hebrides assessment area between 1987 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

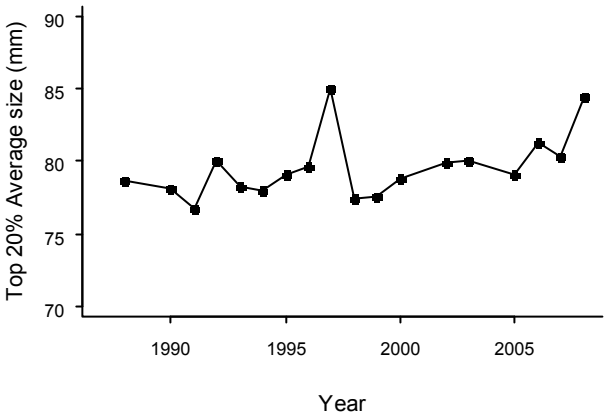

Figure 41: Velvet crab average size of the top 20% individuals sorted by size in the Hebrides assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

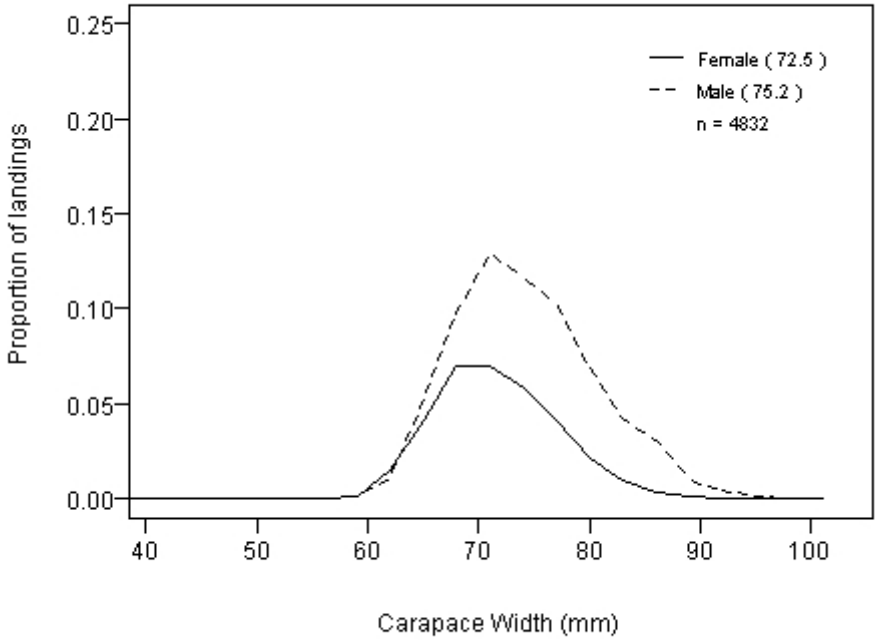

Figure 42: Velvet crab carapace width (mm) frequency histogram for the Hebrides assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 3 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

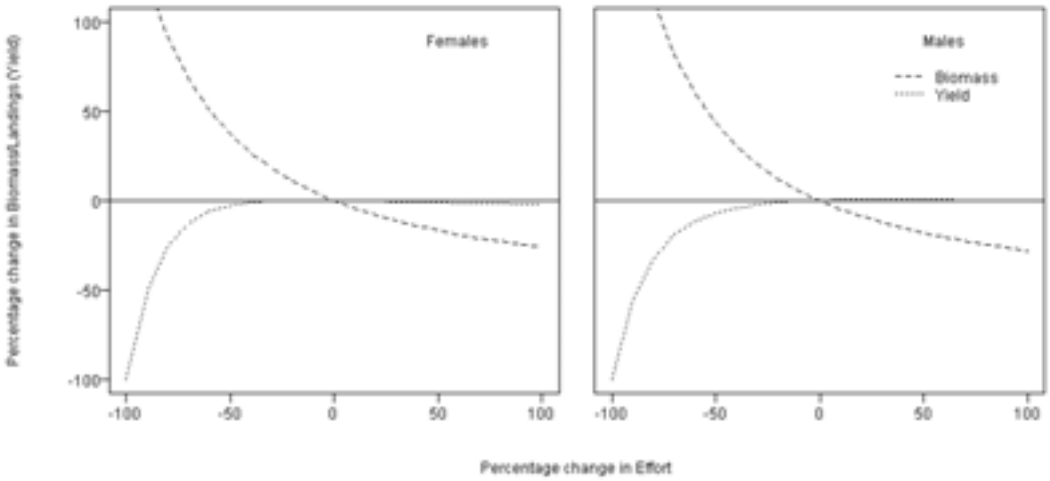

Figure 43: Biomass and Yield-per-recruit predictions for given changes from current effort for velvet crab in the Hebrides assessment area, data from 2006-2008. See Figure 1 for area locations.

Lobster

Market sampling data indicate that the average size of male lobsters is greater than that of females (non-berried) but the size range is similar for both sexes (Figure 46). Both the long term LFDs (Figure 44) and the average size of the largest 20% of individuals (Figure 45) show substantial inter-annual variability, but neither show any systematic changes over the 25 year sampling period. This could indicate that there has been no long-term change in fishing mortality although inter-annual variations may have occurred (the variations in mean length may also be due to sampling variability). LCAs show that male lobsters are being growth over-fished in this area and a reduction in effort of 20% would give a small increase in the yield-per-recruit (Figure 47). The female stock, however, is fished below $F_{MAX.}$

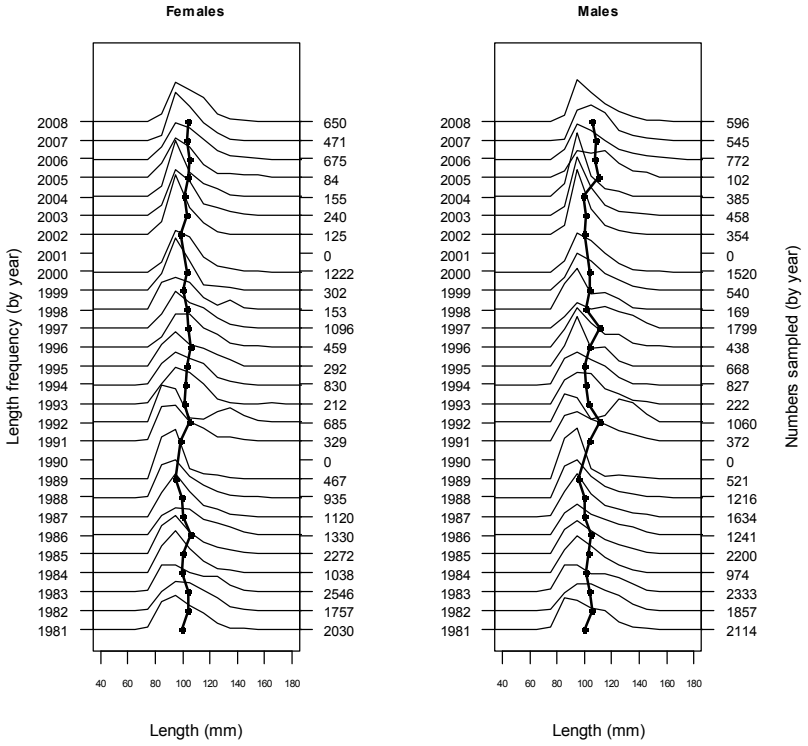

Figure 44: Time series of length frequency for lobster in the Hebrides assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

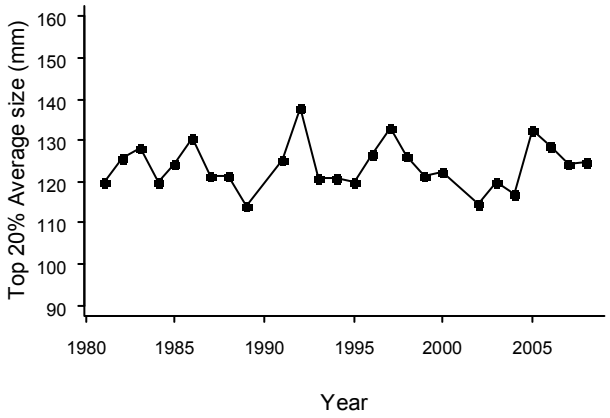

Figure 45: Lobster average size of the top 20% individuals sorted by size in the Hebrides assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

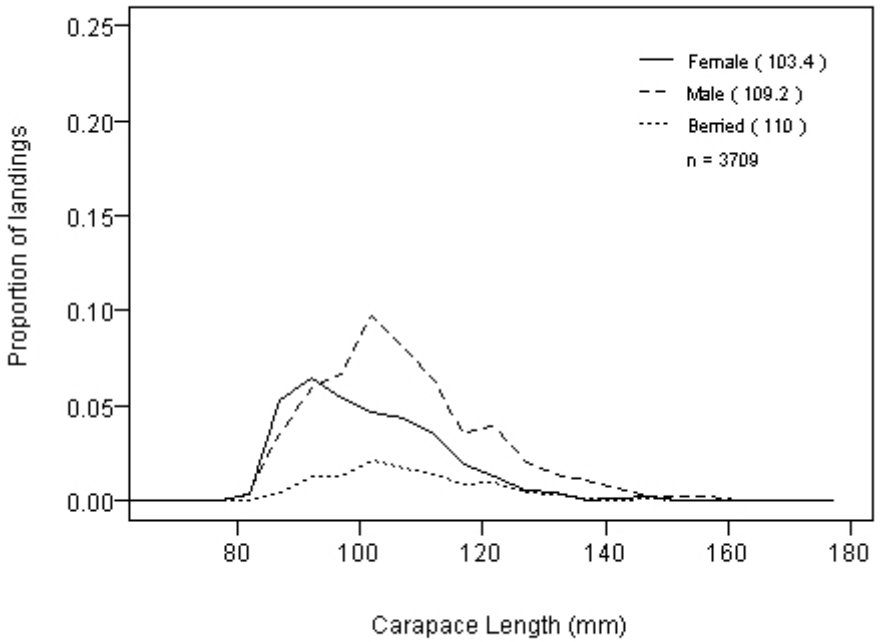

Figure 46: Lobster carapace length (mm) frequency histogram for the Hebrides assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

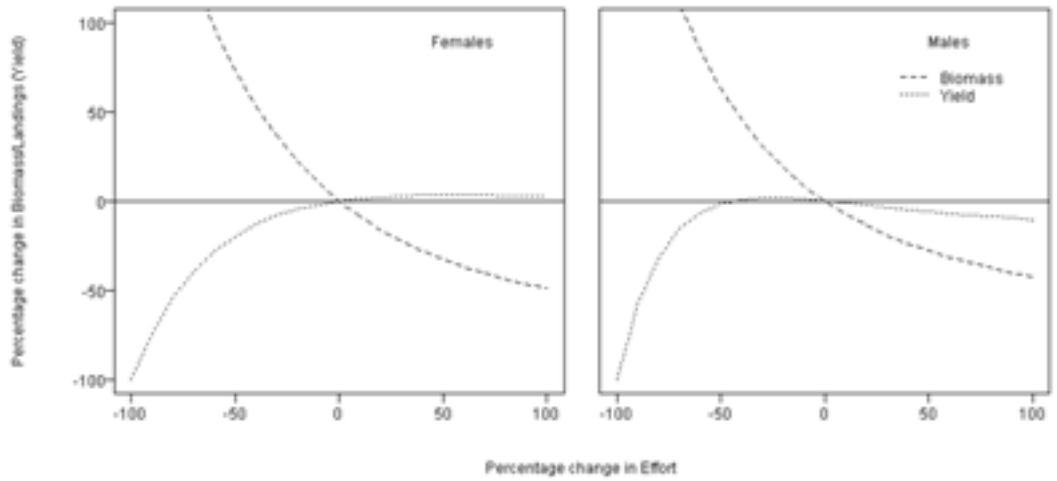

Figure 47: Biomass and Yield-per-recruit predictions for given changes from current effort for lobster in the Hebrides assessment area, data from 2006-2008. See Figure 1 for area locations.

3.2.4 Mallaig

Mallaig is the smallest of the assessment areas and has modest landings of all species. Landings tend to be erratic (Figure 48), the majority being in the second half of the year indicating the fishery is very seasonal, perhaps with only a few vessels fishing for part of the year. Very little market sampling data are available for this area (Table 1) and there are insufficient data for conducting LCA.

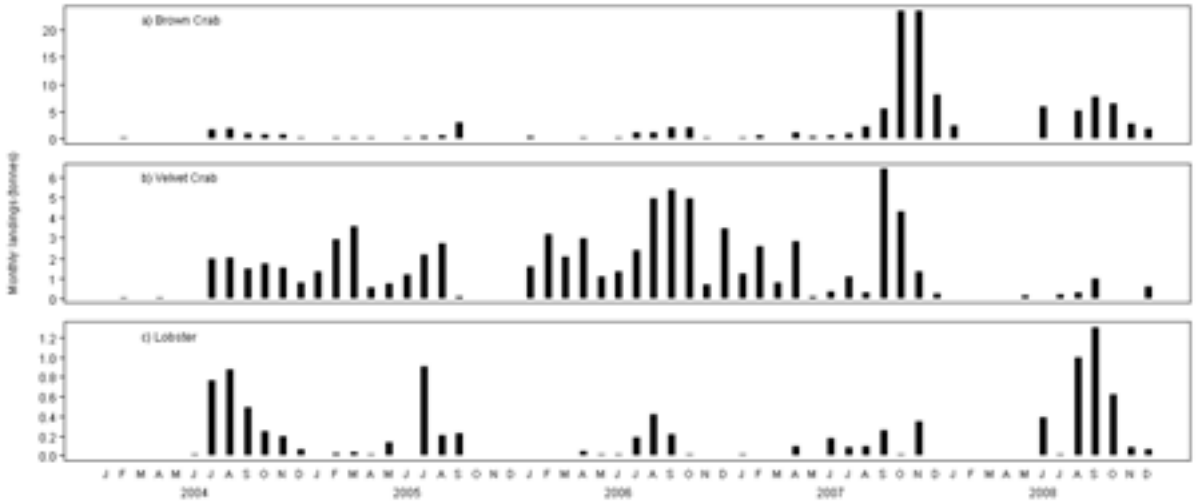

Figure 48: Monthly landings of brown crab, velvet crab and lobster for the Mallaig assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

3.2.5 North Coast

The North Coast area has a small creel fishery, mainly targeting brown crab (Figure 49). There are a few small ports along the coast including Tongue and Bettyhill and the fleet is comprised mostly of small inshore vessels.

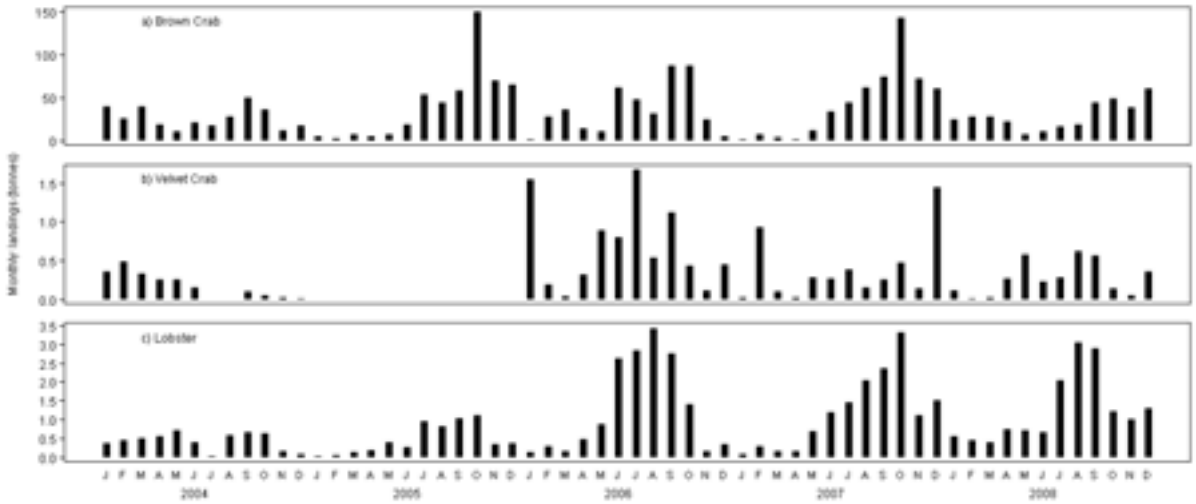

Figure 49: Monthly landings of brown crab, velvet crab and lobster for the North Coast assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

Brown crab landings from the North Coast tend to peak between September and November (Figure 49). The long term landings LFDs and the average size of the largest 20% individuals are shown in Figure 50 and Figure 51, respectively. No clear pattern of size changes in the last ten years is evident. The high variability observed in recent years is likely to be due to the low sampling levels. Approximately 84% of the brown crab sampled landings were females. The number of males in the sampled landings in the last three years has been relatively low, which is reflected in the shape of the averaged LFD (Figure 52). LCAs indicate that female brown crab stocks on the North Coast are being fished just above F_{MAX} whilst the estimated fishing mortality on males is well above F_{MAX} indicating that they are being growth overfished. A 40% reduction in fishing effort would be required to achieve the maximum yield-per-recruit (Figure 53).

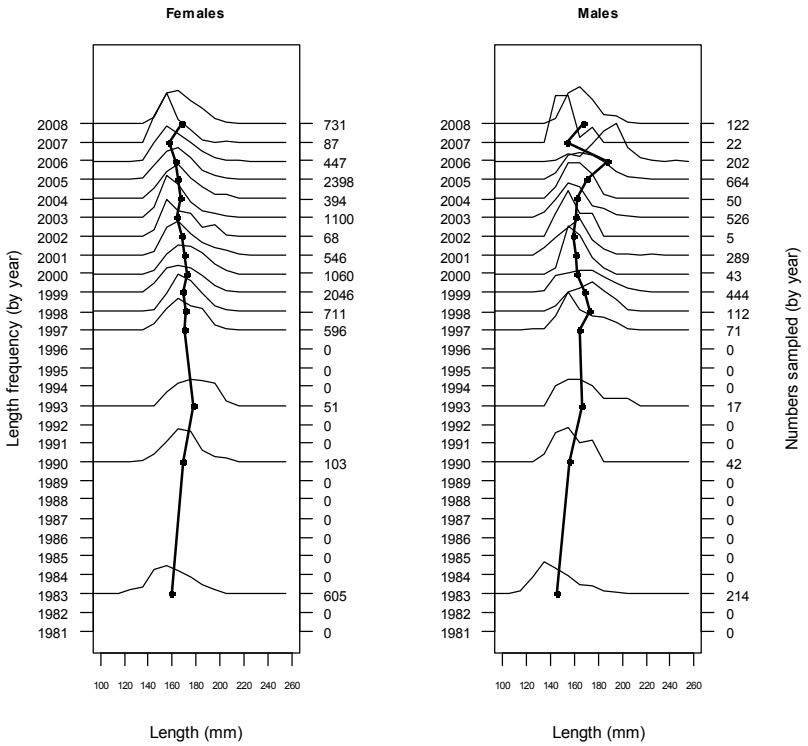

Figure 50: Time series of length frequency for brown crab in the North Coast assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

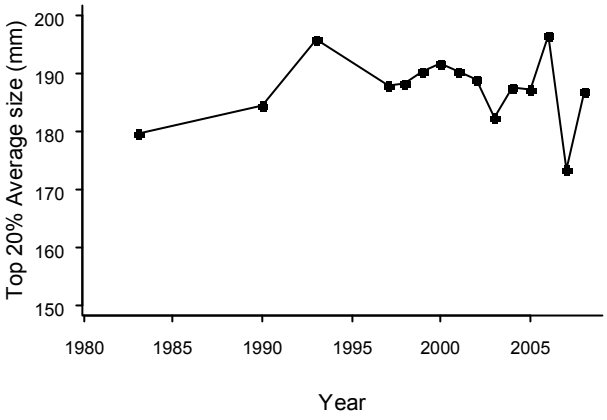

Figure 51: Brown crab average size of the top 20% individuals sorted by size in the North Coast assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

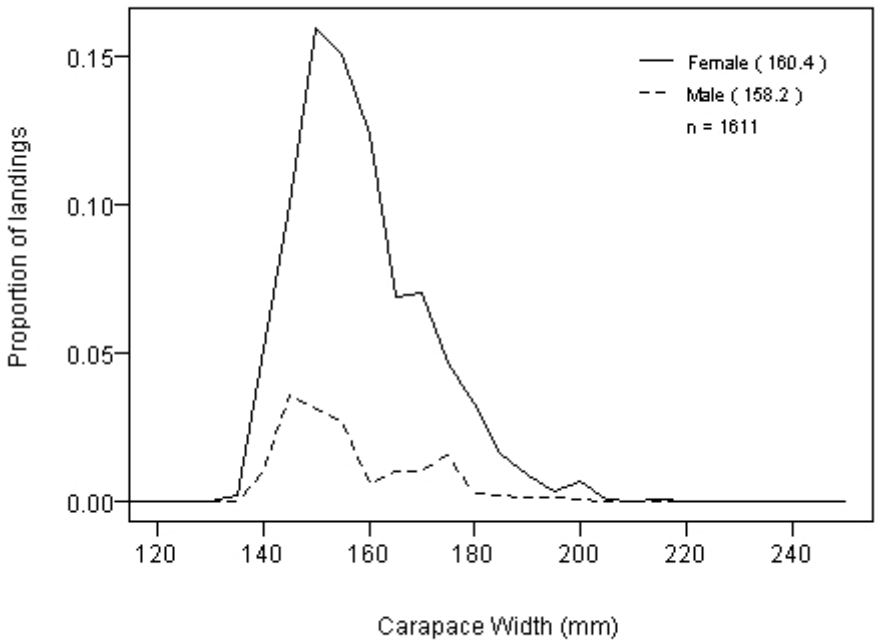

Figure 52: Brown crab carapace width (mm) frequency histogram for the North Coast assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

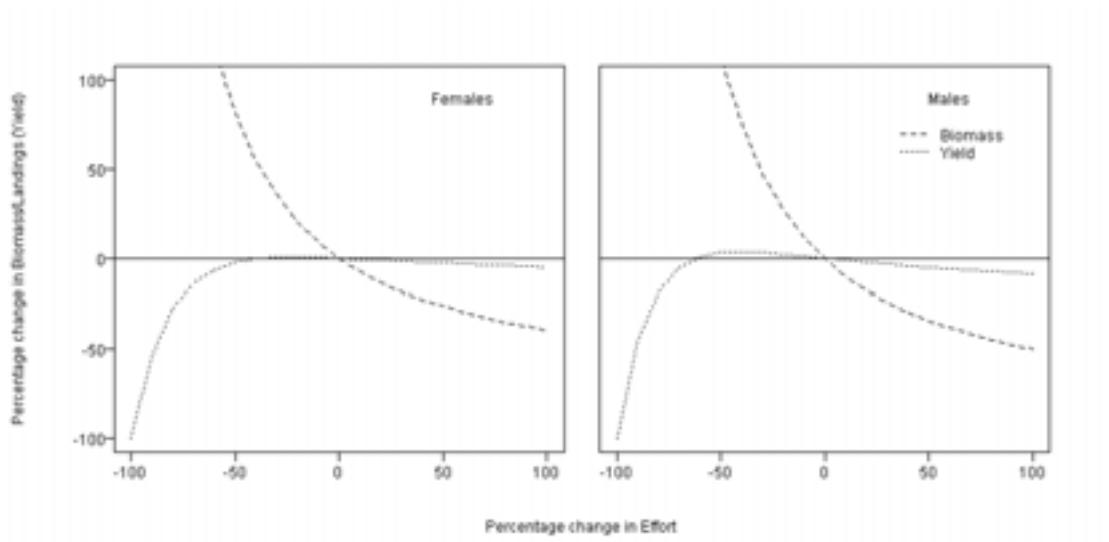

Figure 53: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the North Coast assessment area, data from 2006-2008. See Figure 1 for area locations.

Velvet Crab

Very few velvet crabs are landed in this region and landings are generally a by-catch of the brown crab fishery.

Lobster

Only small volumes of lobster are landed from the North Coast which contributed 1.8% of the Scottish total in 2008. The size range of landed male and female lobsters is similar, with most animals being between 87 and 120 mm (Figure 54). Lobster landings varied on a seasonal basis with landings being greater from July to October each year (Figure 49). Sampling of landings from the area was very limited (2006-2008) and there were insufficient data to carry out LCAs or to investigate long term trends in landings size composition.

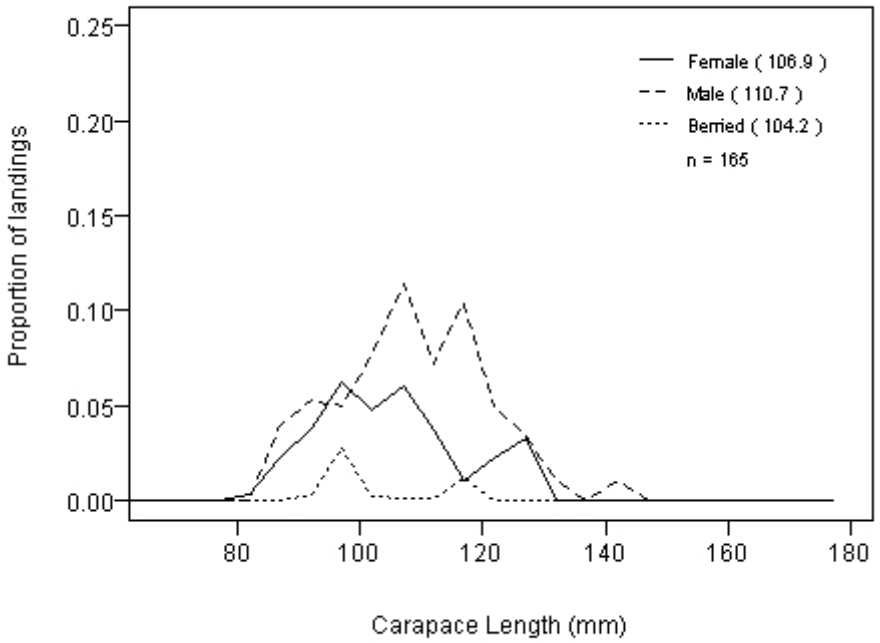

Figure 54: Lobster carapace length (mm) frequency histogram for the North Coast assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

3.2.6 Orkney

Orkney is one of the most important creel fishing areas in Scotland. Both brown crab and lobster landings data show a fairly consistent seasonal pattern over the period 2006-2008 (Figure 55). The landings of velvet crab in this region are amongst the highest from Scottish waters (Table 4).

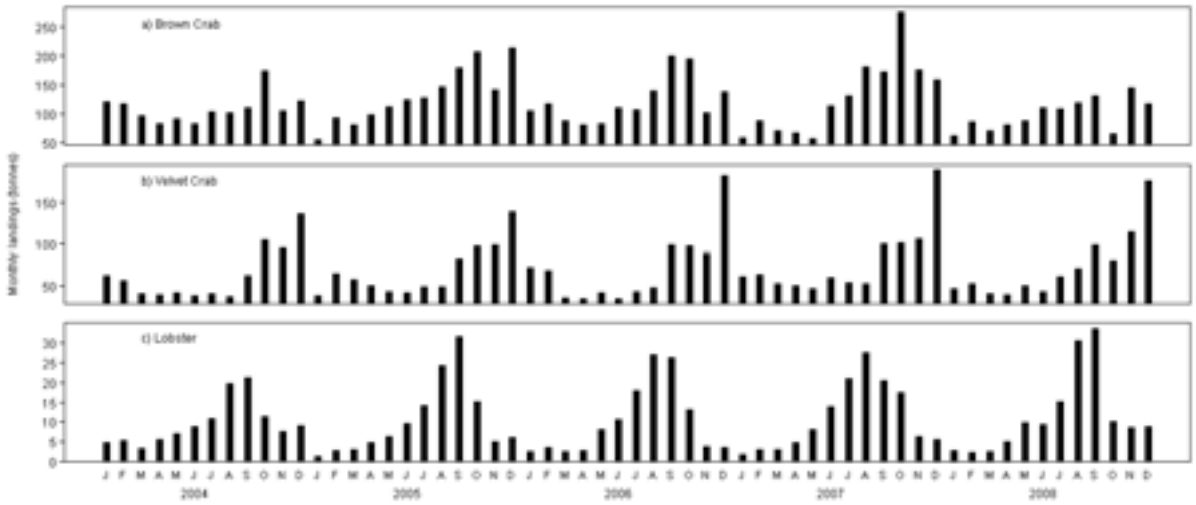

Figure 55: Monthly landings of brown crab, velvet crab and lobster for the Orkney assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

Brown crab landings from the Orkney area tend to peak in September/October of each year, after the lobster landings have peaked and activity in the offshore fishery (Sule and Papa regions) is reduced. Approximately 70% of the brown crabs landed from the Orkney area are females (based on market sampling carried out between 2006 and 2008). Male crabs are on average about 5 mm smaller than the females (Figure 58). The time series of brown crab LFDs from market sampling in Orkney (Figure 56) show occasional occurrences of large numbers of small individuals (1996, 2001, 2005) which may indicate high levels of recruitment in these years. Since the beginning of the time series there seems to have been a general increase in average size of the larger individuals (Figure 57) which potentially could indicate a reduction in fishing mortality (although could also be affected by changing fishing practices). Sampling levels for this stock have been consistently high for most of the time period. LCA suggests that females are being fished at around F_{MAX} (Figure 59). Males are being fished above F_{MAX} and a reduction of effort would result in a small increase (2.5%) in yield-per-recruit.

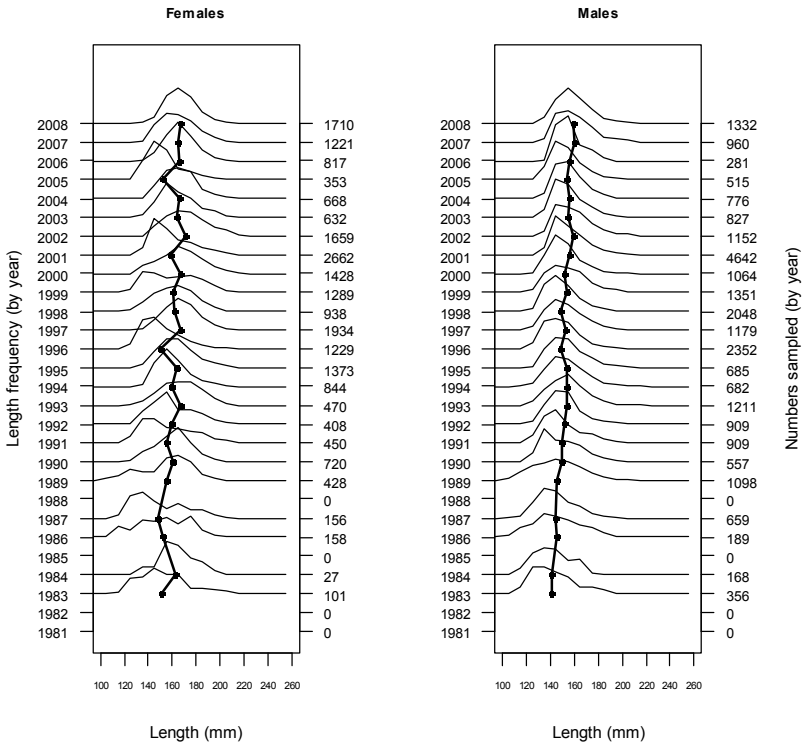

Figure 56: Time series of length frequency for brown crab in the Orkney assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

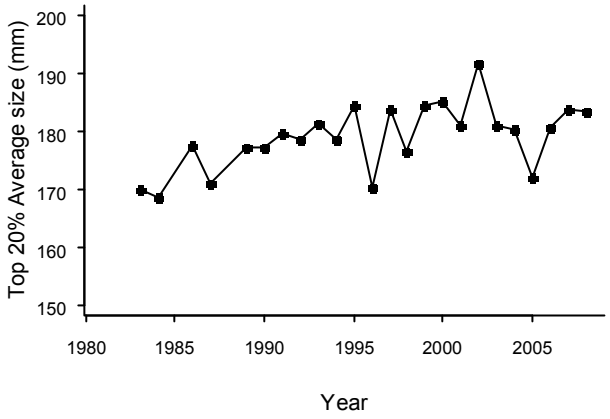

Figure 57: Brown crab average size of the top 20% individuals sorted by size in the Orkney assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

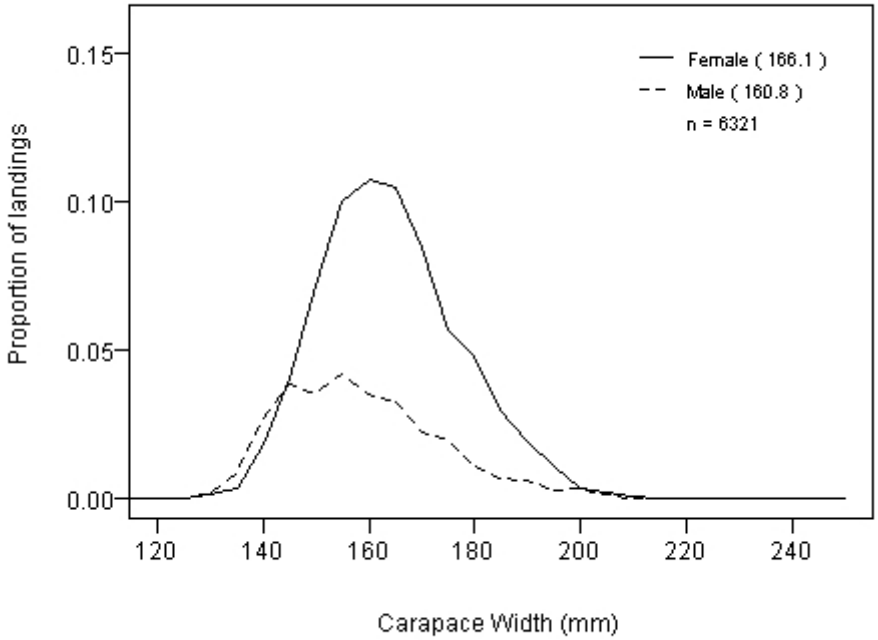

Figure 58: Brown crab carapace width (mm) frequency histogram for the Orkney assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

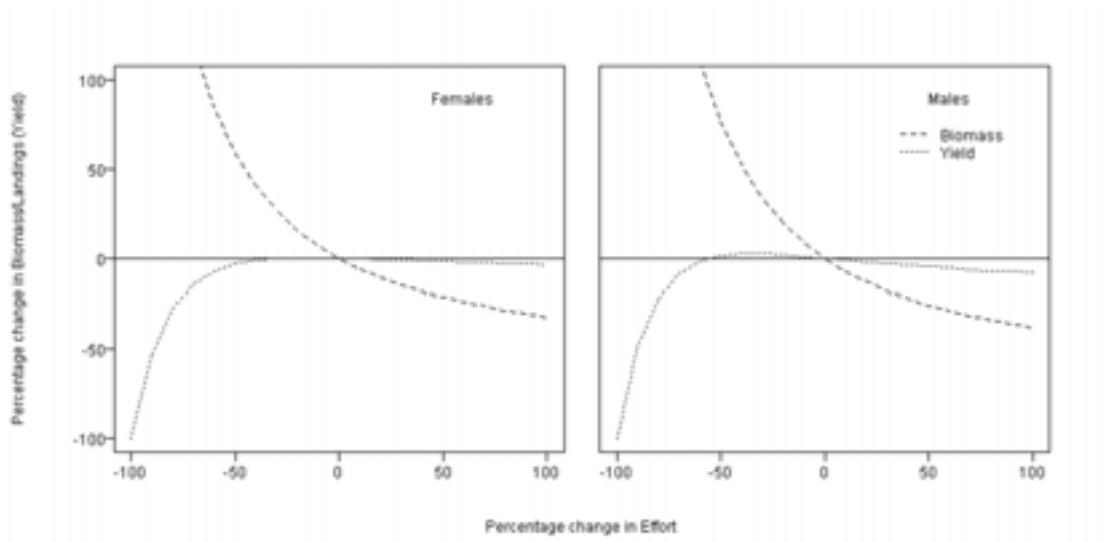

Figure 59: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the Orkney assessment area, data from 2006-2008. See Figure 1 for area locations.

Velvet Crab

In the Orkney area velvet crab landings are highest in the winter months often peaking in November and December. This may be due to a switch in fishing effort at this time of year from the offshore to more inshore grounds where velvet crabs are more common. Males make up approximately 56% of the sampled landings and are a few millimetres larger than the females on average (Figure 62). Both long term landings LFDs (Figure 60) and the average size of the largest 20% individuals (Figure 61) have remained very stable over the last twenty years, suggesting that there has been little change in the level of fishing mortality and little variation in year class strength (although any variability in recruitment could be masked by associated changes in discard rates). The LCA indicates that both male and female velvet crabs are growth overfished (Figure 63). The yield-per-recruit of female stocks in particular would benefit from a reduction in fishing effort.

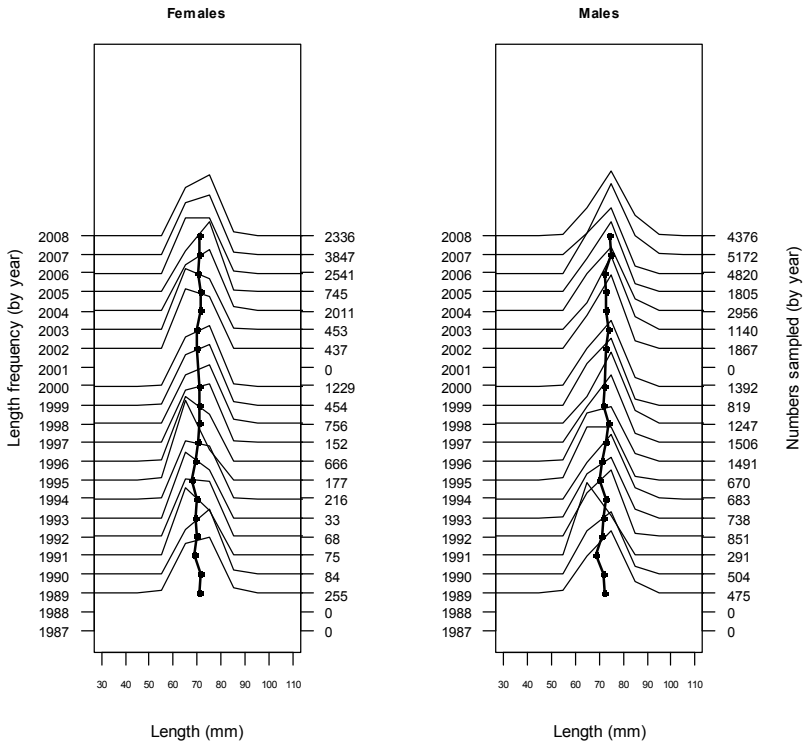

Figure 60: Time series of length frequency for velvet crab in the Orkney assessment area between 1987 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

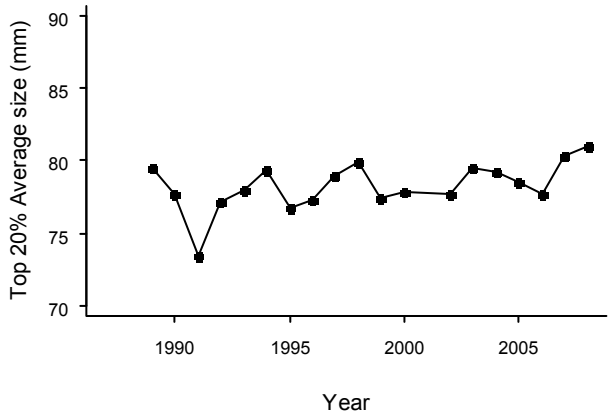

Figure 61: Velvet crab average size of the top 20% individuals sorted by size in the Orkney assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

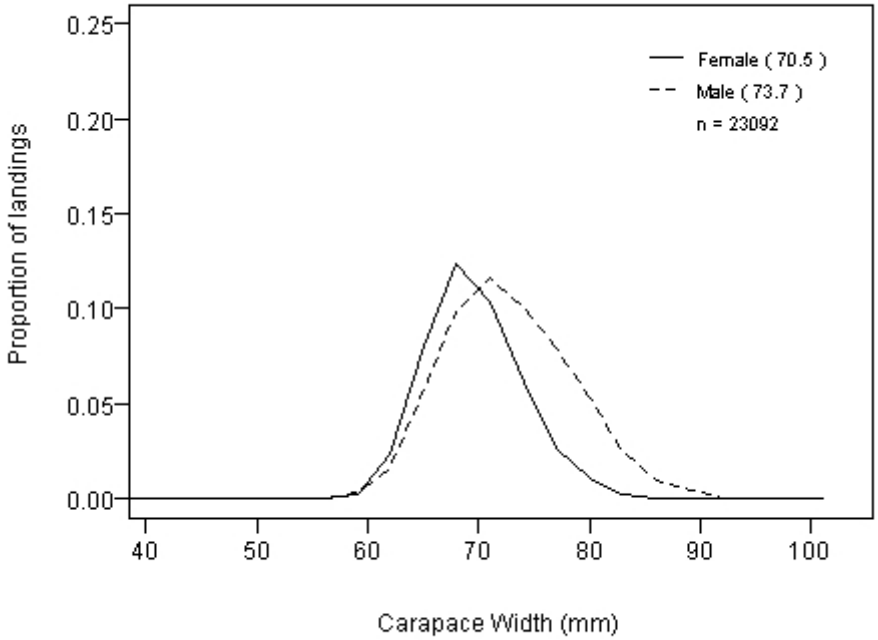

Figure 62: Velvet crab carapace width (mm) frequency histogram for the Orkney assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 3 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

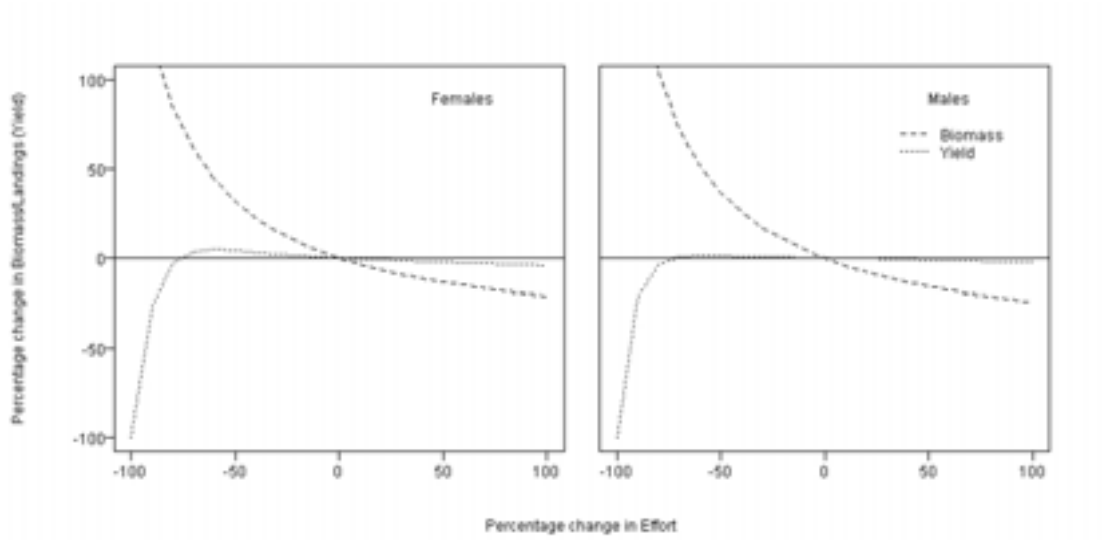

Figure 63: Biomass and Yield-per-recruit predictions for given changes from current effort for velvet crab in the Orkney assessment area, data from 2006-2008. See Figure 1 for area locations.

Lobster

Between 2002 and 2005 approximately 30% of the total reported lobster landings into Scotland were taken in the Orkney area. This figure dropped to around 16% in 2006-2008, possibly due to an increase in the reported landings from the East and South East areas (there was no drop in the actual landings from Orkney) (Table 4). Landings of lobster peak between July and September. Both long term landings LFDs (Figure 64) and the average size of the largest 20% individuals (Figure 65) have remained stable in recent years, suggesting that the fishing mortality has been relatively stable. The reduction in mean size between 1980 and 1990 may be associated with increasing fishing mortality at this time (a period during which landings increased). Based on the MSS market sampling data, it appears that male and female lobsters landed from the Orkney area have very similar size distributions and landed in equal proportions (Figure 66). LCA indicates that male lobsters are being fished at a level above F_{MAX}. A reduction in fishing effort of approximately 40% would be needed to achieve the maximum yield-per-recruit of the male lobsters which would represent an increase of about 5% of the current value (Figure 67). Females are being fished just below $F_{MAX.}$

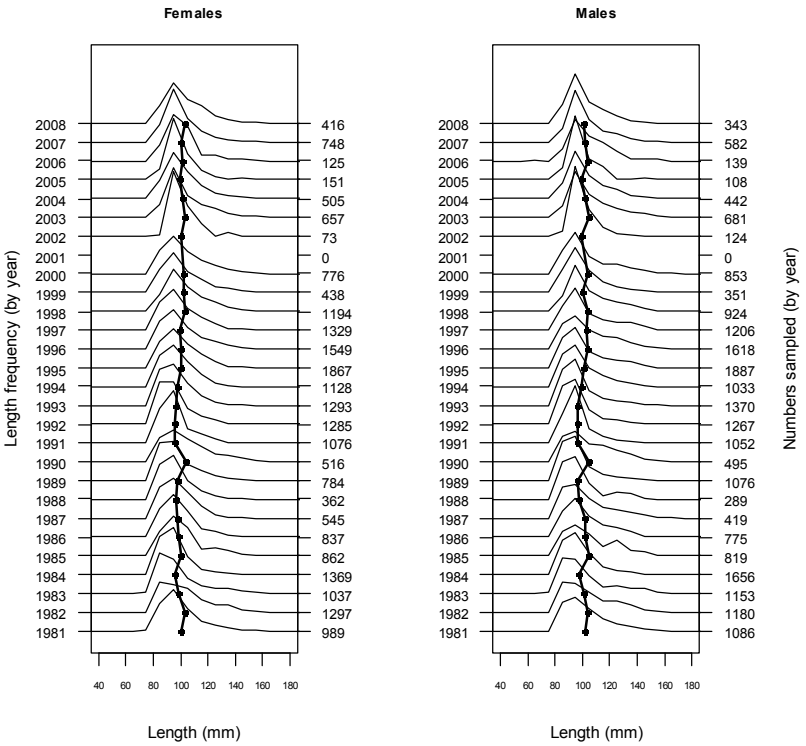

Figure 64: Time series of length frequency for lobster in the Orkney assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

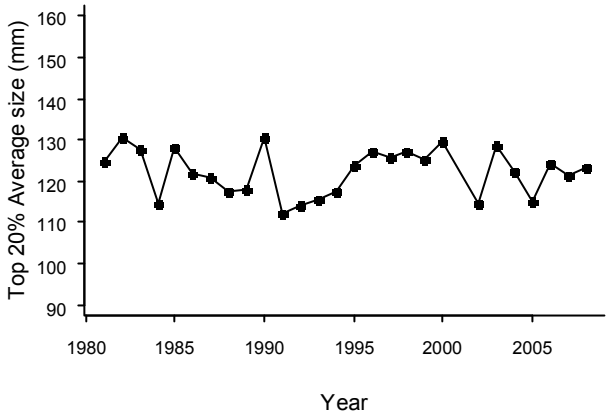

Figure 65: Lobster average size of the top 20% individuals sorted by size in the Orkney assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

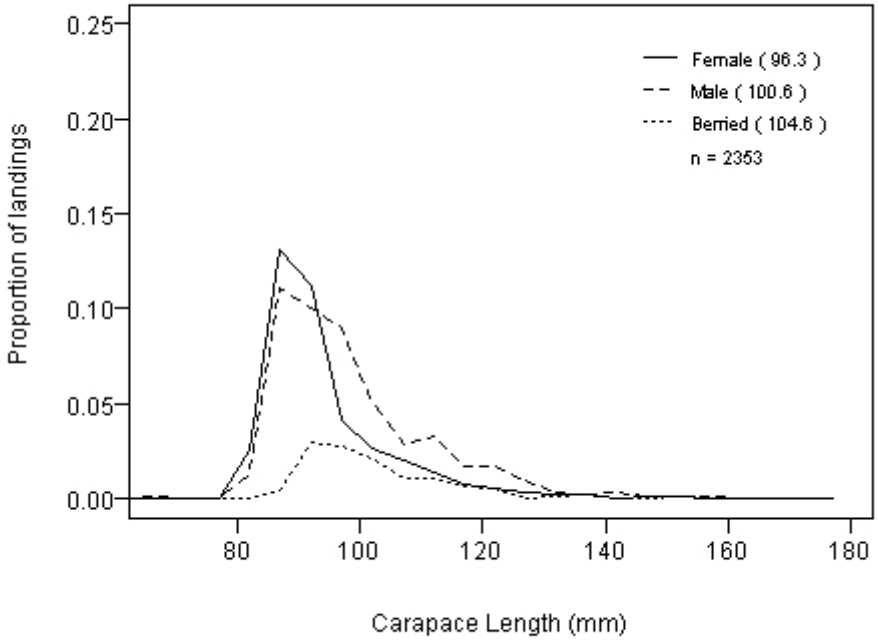

Figure 66: Lobster carapace length (mm) frequency histogram for the Orkney assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

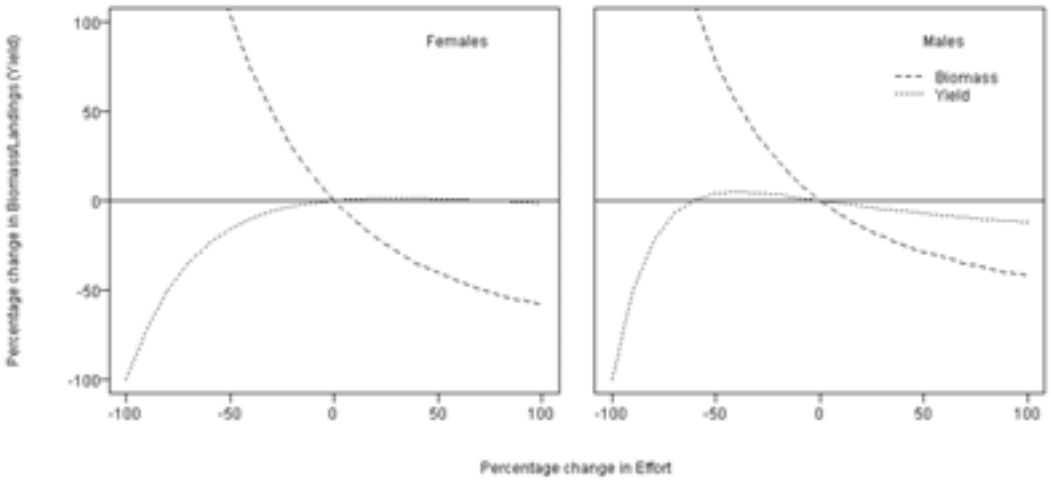

Figure 67: Biomass and Yield-per-recruit predictions for given changes from current effort for lobster in the Orkney assessment area, data from 2006-2008. See Figure 1 for area locations.

3.2.7 Papa Bank

The Papa Bank fishery is relatively new and crab creel landings data from the area have only been recorded since 1996 and length frequency data from sampled landings are available from 2000. The area is fished almost exclusively by large vivier crab vessels, landing into Shetland and north coast ports. Some vessels only fish this area seasonally (in summer) whilst others fish here all year round.

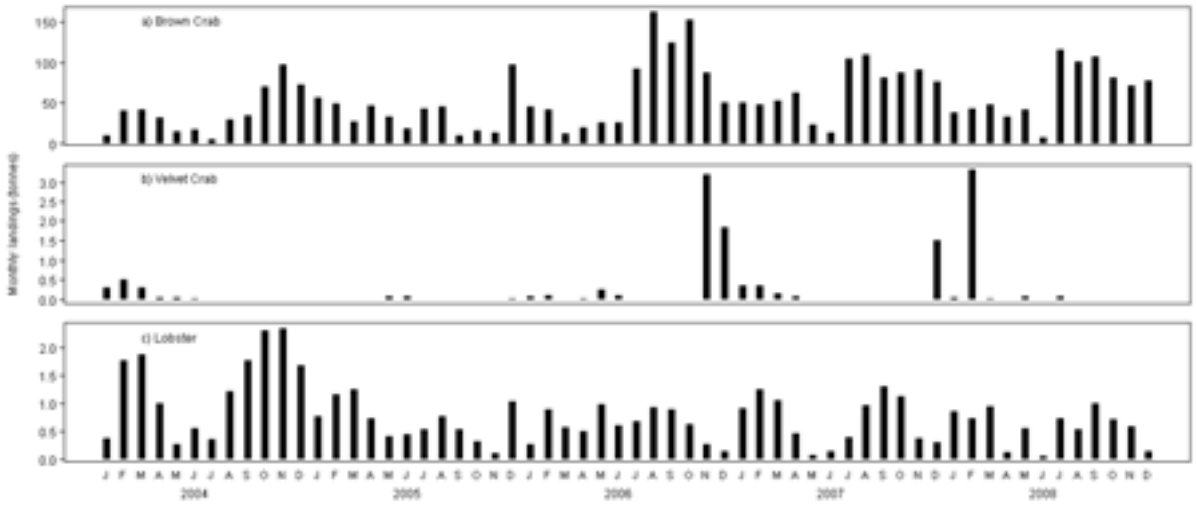

Figure 68: Monthly landings of brown crab, velvet crab and lobster for the Papa assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

Typically, landings of brown crab from Papa peak in September and October, with around 100 tonnes landed each month (Figure 68). Females made up 87% of the sampled landings in 2006 (not shown) which may be a reflection of the population present or it may be due to seasonal differences in catchability. Little is known about the composition of the offshore stock (or component of stock) or if it is in fact a previously unexploited extension of the inshore stock. There was no sampling of Papa Bank landings in 2007 and 2008 therefore no assessments were carried out for this area.

Velvet Crab

Very low landings of velvet crab are generally reported from Papa with the exception of November and December 2006, December 2007 and February 2008 when landings were higher, peaking at around 1.5 tonnes.

Lobster

Lobsters from Papa comprised around 1% of the total Scottish landings between 2006 and 2008. Lobster abundance is generally thought to be low offshore and it is likely that landings from Papa are incidental catches in the targeted brown crab fishery.

3.2.8 Shetland

Since 2000 the crab and lobster stocks in the Shetland assessment area have been managed under The Shetland Islands Regulated Fishery (Scotland) Order, 1999, by the Shetland Shellfish Management Organisation (SSMO). The monthly data from SSMO logbooks show distinct seasonality in the crab and lobster landings (Figure 69). These data were provided by NAFC Marine Centre with permission from the SSMO.

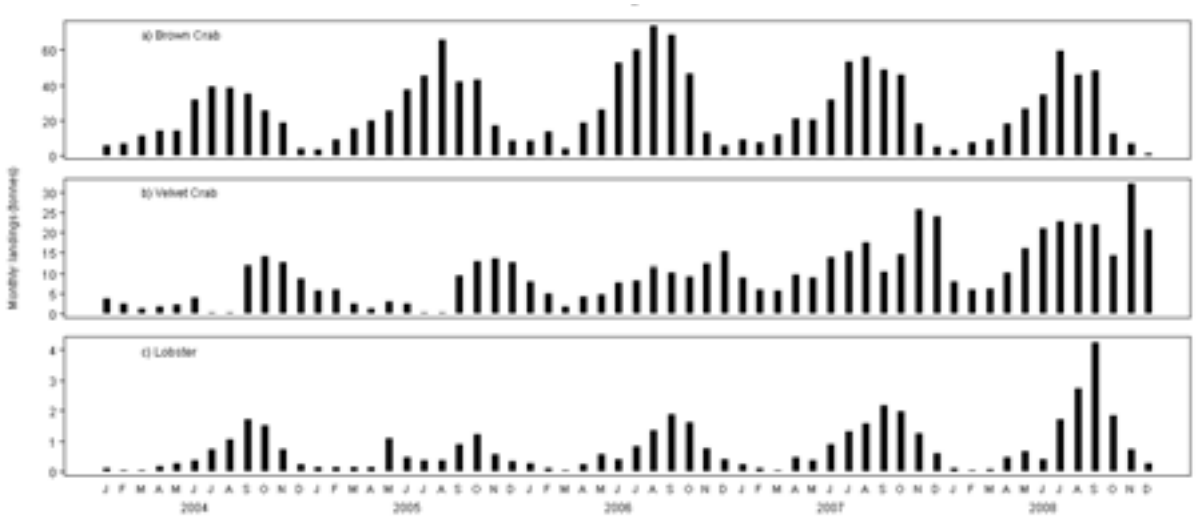

Figure 69: Monthly landings of brown crab, velvet crab and lobster for the Shetland assessment area from 2004-2008. Data are from Shetland Shellfish Management Organisation logbooks. See Figure 1 for area locations.

Brown Crab

Data from FIN suggest that up to 6% of the total brown crab landed in Scotland is from the Shetland assessment area. Data from the SSMO logbooks show that there is a seasonal pattern with higher landings between June and October. Both long term LFDs (Figure 70) and the average size of the largest 20% individuals (Figure 71) have remained relatively stable in recent years. In the late 1980s the LFDs appear to contain a greater proportion of smaller individuals which may indicate that recruitment was high during this period, but could also be due to higher retention rates of small individuals. Sampling of landings show that males and females are landed in approximately equal proportions (Figure 72). The results of the LCA for brown crab in Shetland indicate that females are being fished below F_{MAX} whereas males are being fished slightly above F_{MAX} (Figure 73).

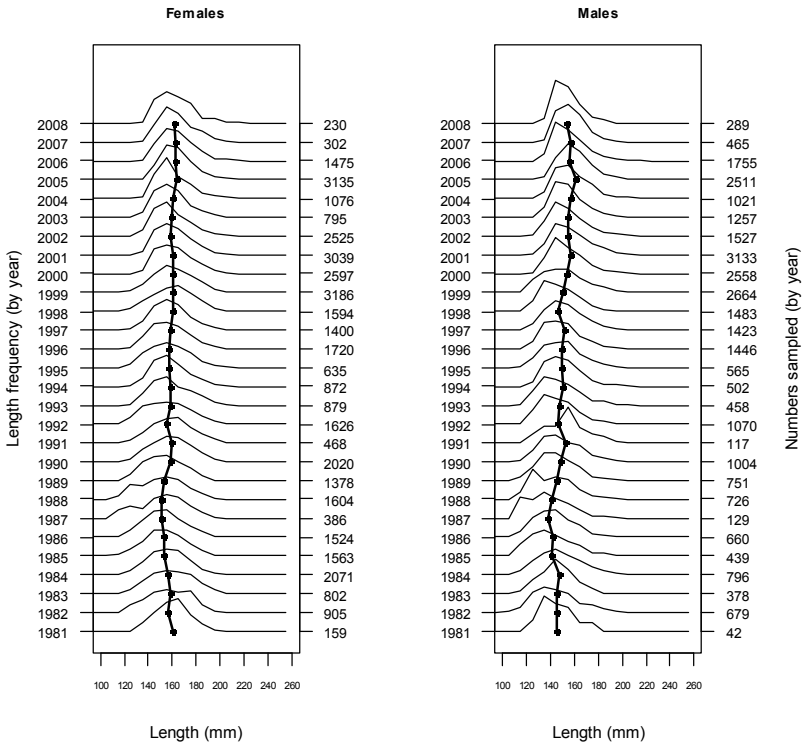

Figure 70: Time series of length frequency for brown crab in the Shetland assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

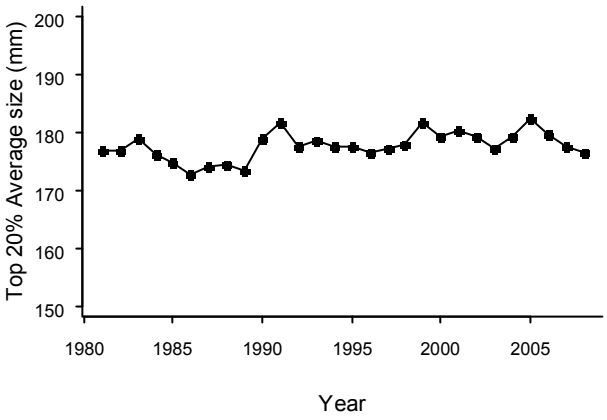

Figure 71: Brown crab average size of the top 20% individuals sorted by size in the Shetland assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

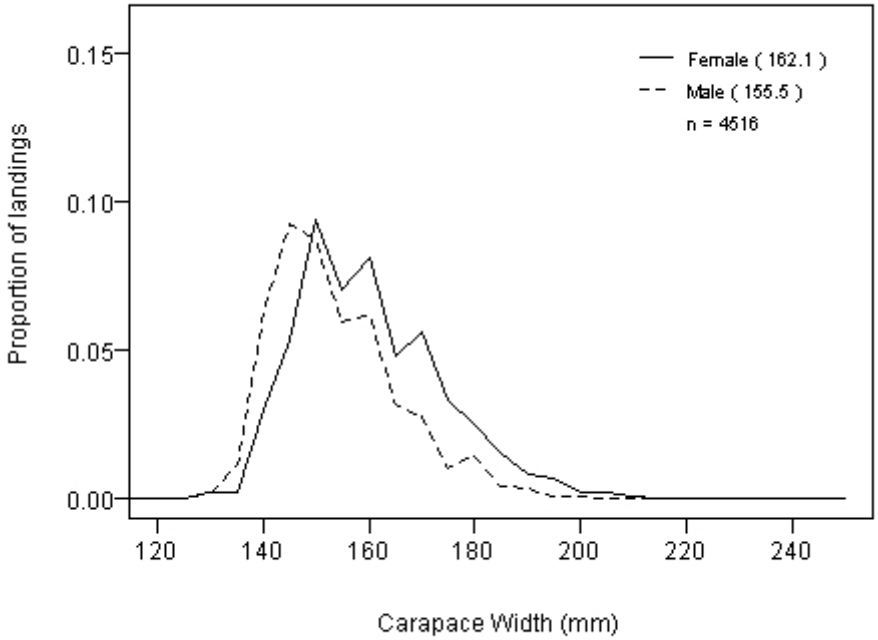

Figure 72: Brown crab carapace width (mm) frequency histogram for the Shetland assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. Data are from MSS market sampling programme. n= numbers measured.

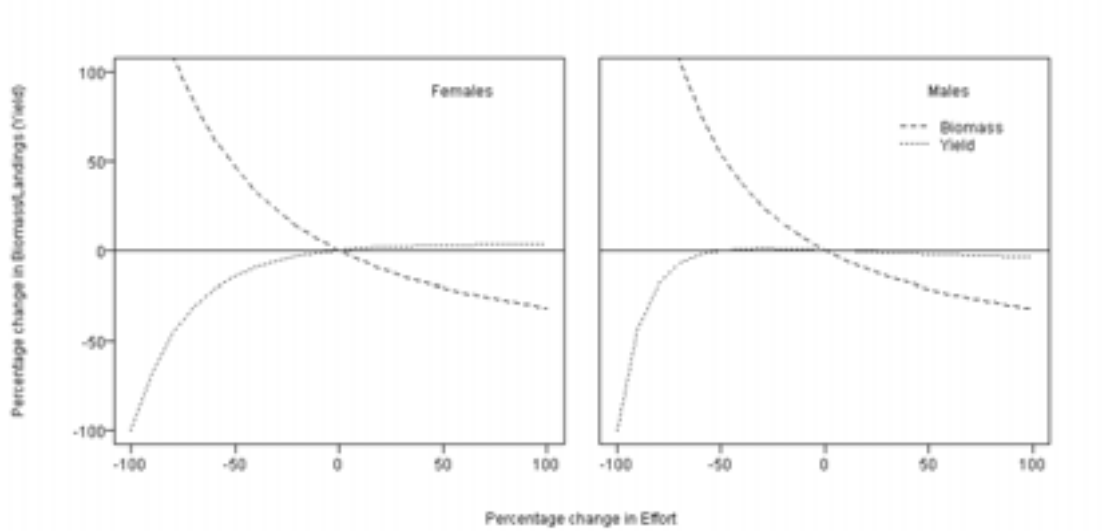

Figure 73: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the Shetland assessment area (MSS length frequency data raised to the FMD landings data, averaged over 2006-2008, see Figure 1 for area locations.

Velvet Crab

Shetland has a significant velvet crab fishery which has increased in the last five years with a maximum landing of 200 tonnes in 2008. The MLS of velvet crabs is controlled by the RO and is currently 70 mm compared to 65 mm for the rest of Scotland. As the length frequency distribution data (Figure 74) are for catch samples (landings and discards) it was not possible to estimate the mean size and sex ratio of the landed catch. For the length cohort analysis it was assumed that all animals under the MLS were discarded, with a 99% survival rate and that all of the catch over the minimum landing size were landed. LCA indicates that velvet crab in Shetland (both males and females) are currently exploited slightly below F_{MAX} (Figure 75).

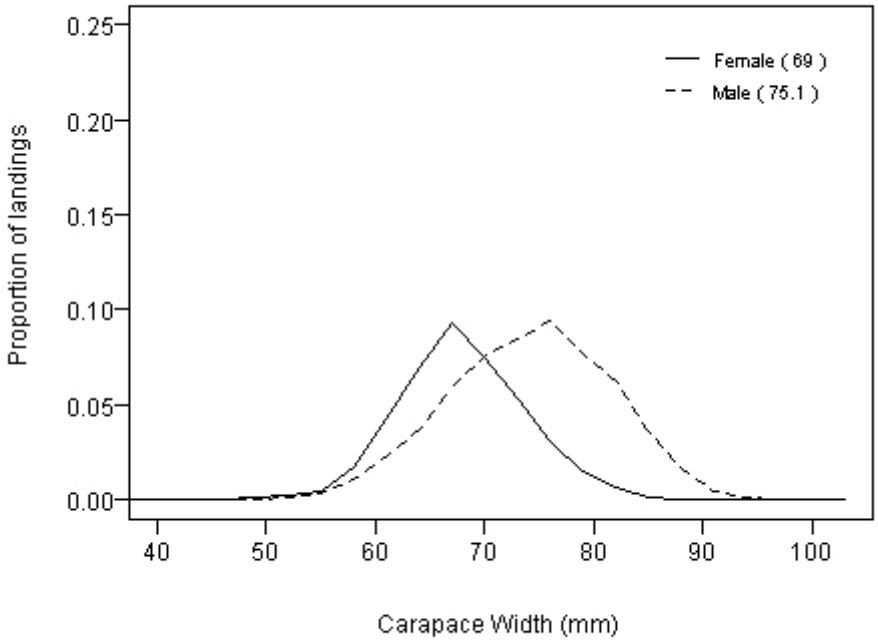

Figure 74: Velvet crab carapace width (mm) frequency histogram for the Shetland assessment area. Data are NAFC Marine Centre carapace width frequency data (from commercial vessels, landings and discards) raised to Shetland Shellfish Management Organisation logbook landings data and averaged over the period 2006-2008. They were provided by NAFC Marine Centre with the permission of the SSMO. The data presented are aggregated by 3 mm increments and shown as a proportion of the total catch. Numbers in brackets are mean widths.

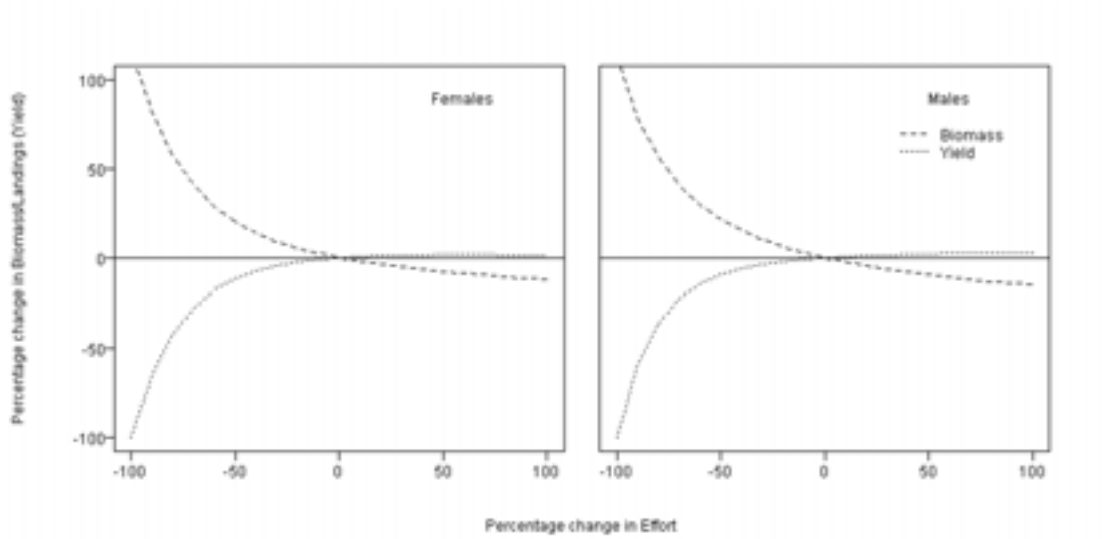

Figure 75: Biomass and Yield-per-recruit predictions for given changes from current effort for velvet crab in the Shetland assessment area (length frequency data averaged over 2006-2008, provided by NAFC Marine Centre with the permission of the SSMO. See Figure 1 for area locations.

Lobster

Lobster landings from Shetland showed a seasonal trend between 2006 and 2008 peaking in September each year. The minimum landings size in Shetland is 90 mm CL, 3 mm greater than the rest of Scotland. The length frequency distributions of the sampled landings show that the size of males and females landed were similar with a mean size ca. 10 mm above the MLS (Figure 76). No information on the size of berried animals was available. LCA predicted that an increase in equilibrium yield could be achieved if the effort was reduced by about 30% for female lobsters while males are being fished just below F_{MAX} (Figure 77).

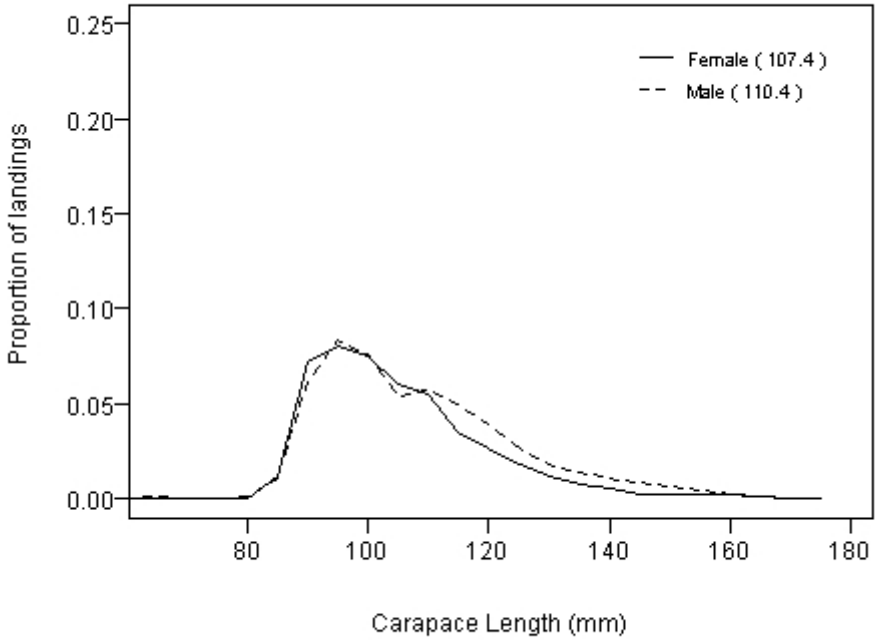

Figure 76: Lobster carapace length (mm) frequency histogram for the Shetland assessment area. Data are NAFC Marine Centre carapace length frequency data raised to Shetland Shellfish Management Organisation logbook landings data and averaged over the period 2006-2008. These data were provided by NAFC Marine Centre with the permission of the SSMO. The data presented are aggregated by 5 mm increments and shown as a proportion of the total catch. Numbers in brackets are mean lengths.

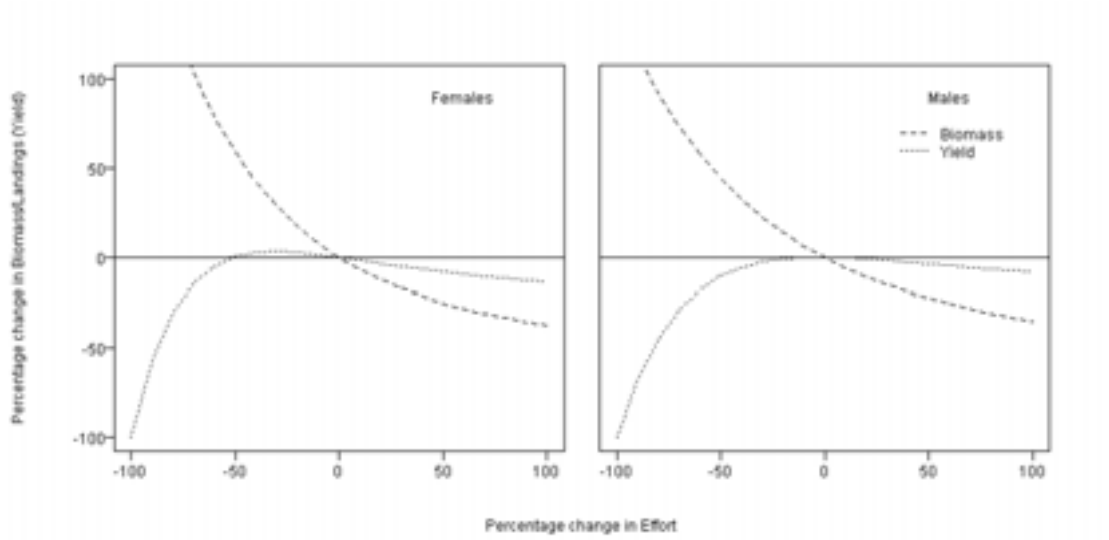

Figure 77: Biomass and Yield-per-recruit predictions for given changes from current effort for lobster in the Shetland assessment area (length frequency data averaged over 2006-2008, provided by NAFC Marine Centre with the permission of the SSMO, see Figure 1 for area locations.

3.2.9 South East

The South East area is one of most important for lobster fishing in Scotland. The main ports include Eyemouth, Dunbar, Port Seton and the fishing villages on the East Neuk of Fife from Pittenweem to St Andrews. Over the past four years an increasing amount of brown crab, velvet crab and lobster has been landed from this area (Figure 78). Crabs from the South East tend to be smaller than those from the other assessment areas.

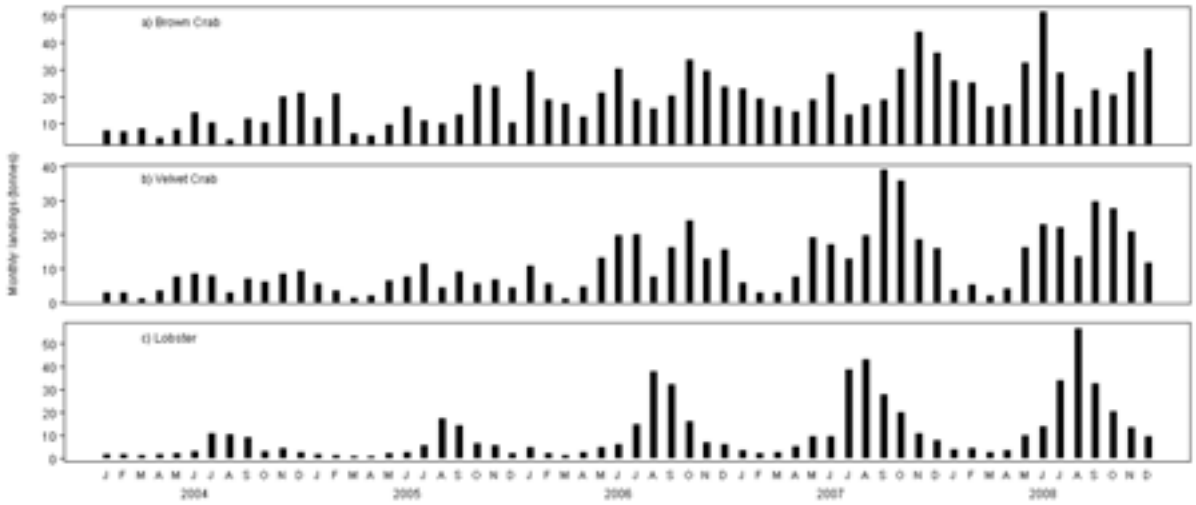

Figure 78: Monthly landings of brown crab, velvet crab and lobster for the South East assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

There is no clear seasonality to the brown crab fishery in the South East (Figure 78). Landings from this area are relatively well sampled. Size distributions of males and females are similar but males predominate in the landings sampled (Figure 81). The brown crab LFDs (Figure 79) show occasional high numbers of small individuals (in the late 1990s) which may be indicative of good recruitment in these years. The mean size in the landings increases for the first 20 years of the time series and then decreases over the last 10 years, especially among larger individuals (Figure 80). Landings declined over the first part of this time period, suggesting that the increase in mean size may have been a result of reduced fishing mortality, with the subsequent decrease in size potentially related to more recent increases in fishing mortality. LCAs indicate that both male and female brown crabs are growth overfished - a slight increase in yield-per-recruit would be achieved in the long term if effort was reduced (Figure 82).

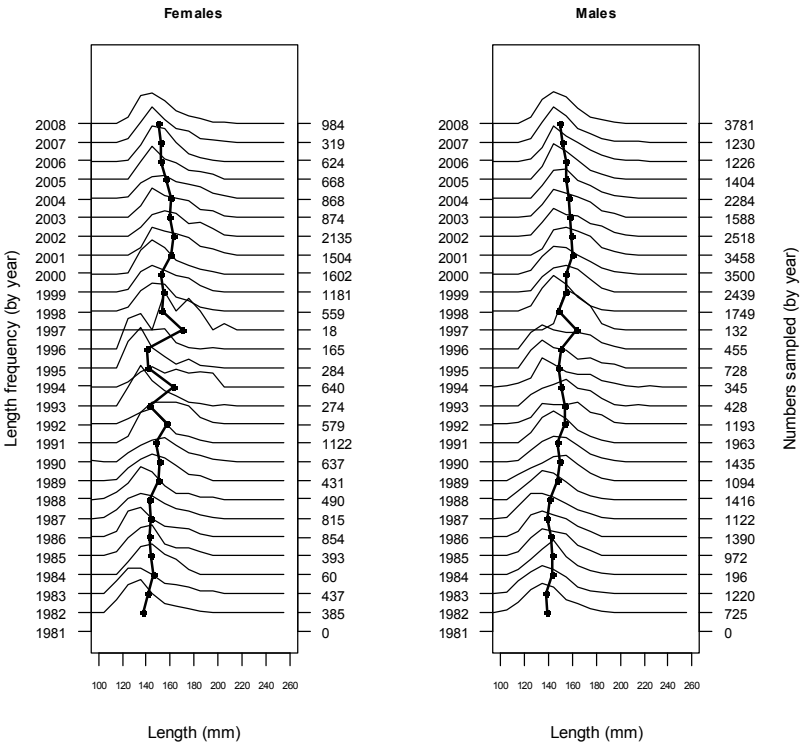

Figure 79: Time series of length frequency for brown crab in the South East assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

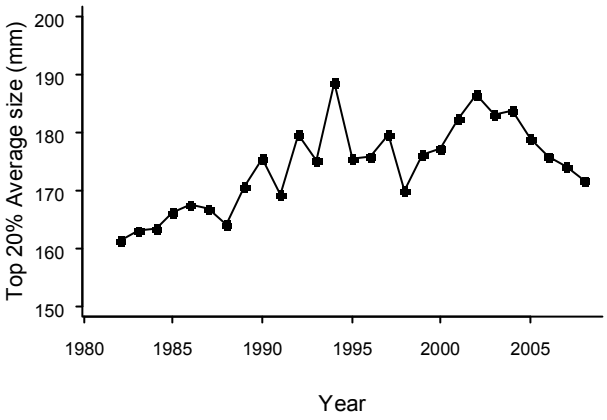

Figure 80: Brown crab average size of the top 20% individuals sorted by size in the South East assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

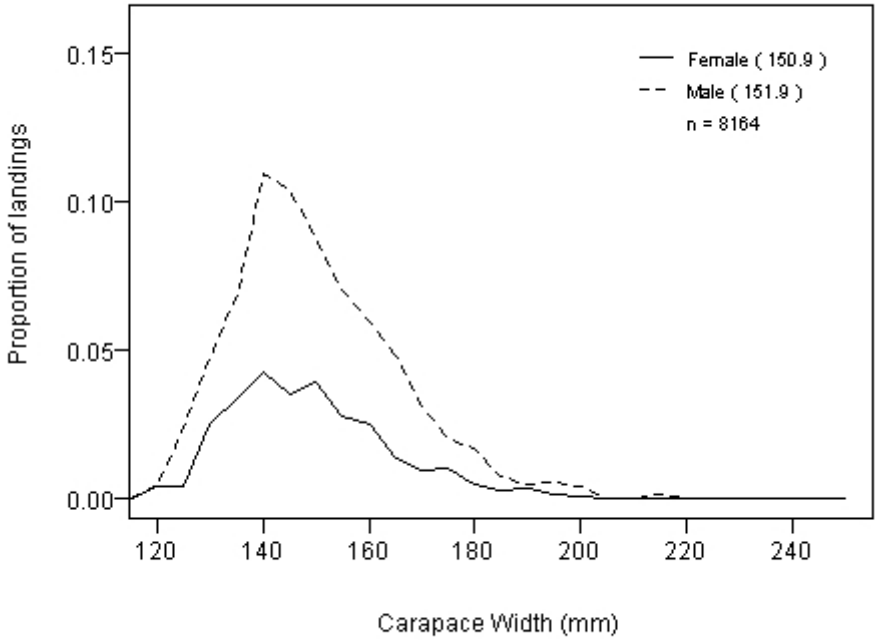

Figure 81: Brown crab carapace width (mm) frequency histogram for the South East assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

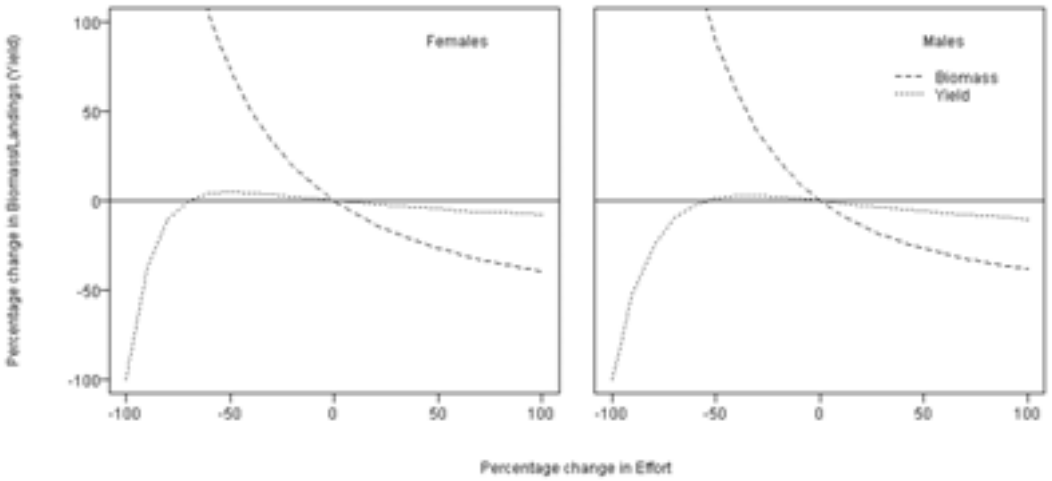

Figure 82: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the South East assessment area, data from 2006-2008. See Figure 1 for area locations.

Velvet Crab

Fishermen have reported a recent increase in velvet crab catches throughout the year in the Firth of Forth/Fife area. Although this species has not been specifically targeted in the past there is a growing market for the velvet crabs and a Vivier lorry collects animals from the East Coast once a week. The long term LFDs and the mean size of the largest 20% individuals are shown in Figure 83 and Figure 84, respectively. The average size of the larger individuals appears to have been relatively stable over the last ten years, although trends would be difficult to detect given that sampling levels are low. The mean size of both male and female velvet crab from the South East is over 70 mm and males made up approximately 77% of the sampled landings (Figure 85). LCA yield-per-recruit curves indicate that both male and female velvet crab stocks in the South East are being fished close to F_{MAX} (Figure 86).

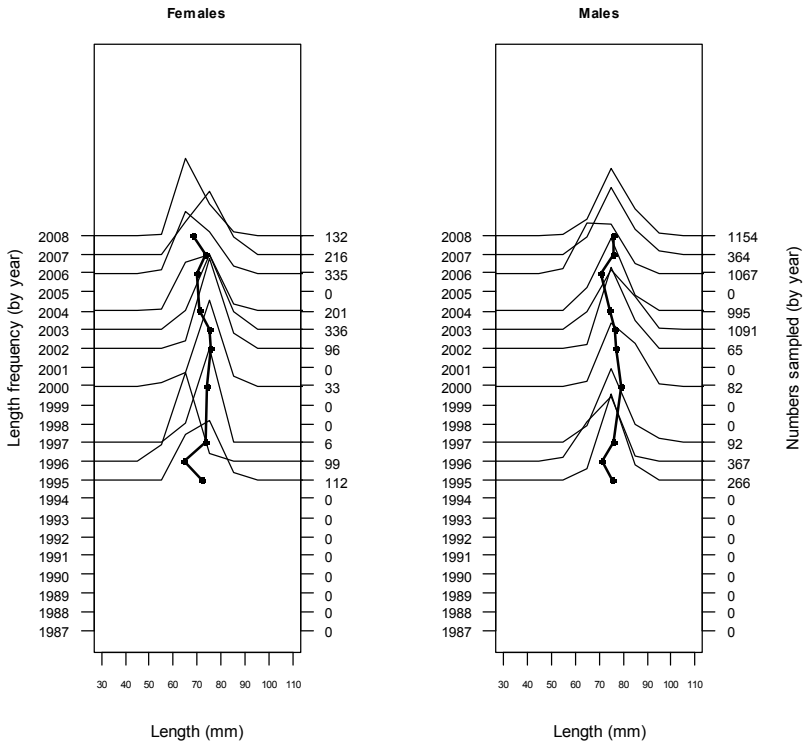

Figure 83: Time series of length frequency for velvet crab in the South East assessment area between 1987 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

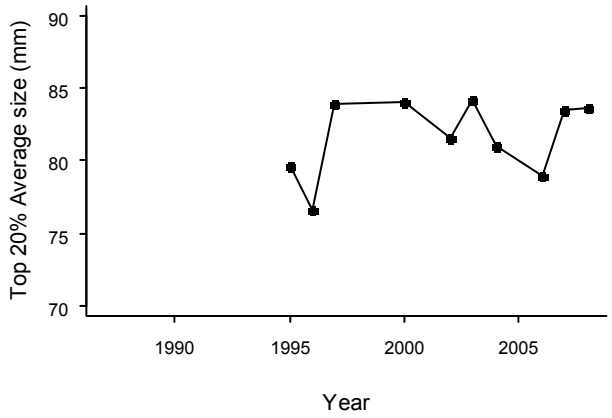

Figure 84: Velvet crab average size of the top 20% individuals sorted by size in the South East assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

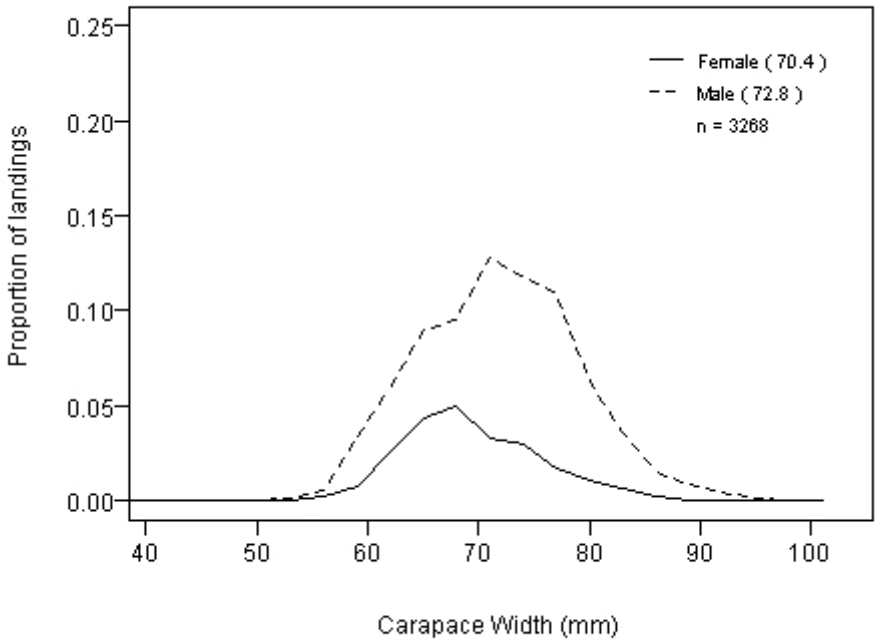

Figure 85: Velvet crab carapace width (mm) frequency histogram for the South East assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 3 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

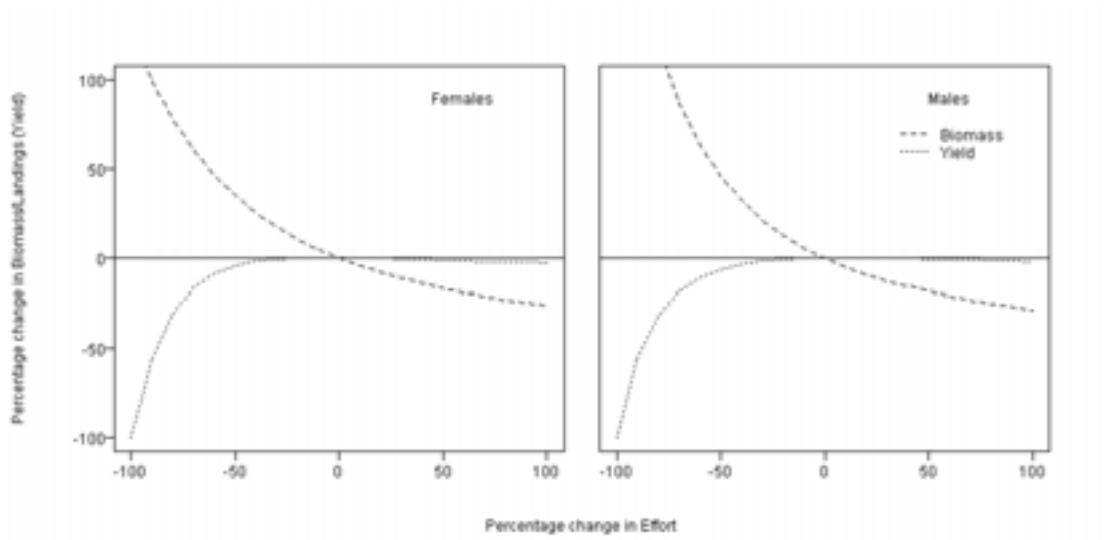

Figure 86: Biomass and Yield-per-recruit predictions for given changes from current effort for velvet crab in the South East assessment area, data from 2006-2008. See Figure 1 for area locations.

Lobster

Lobster landings from the South East area have fluctuated between 50 and 150 tonnes per annum since 1975 (Figure 7). The fishery is currently one of Scotland's largest lobster fisheries and from 2006 to 2008 represented about 21% of the national landings (Table 4). There is a strong seasonal pattern in landings with the majority of animals being landed between July and September. Lobsters from the South East assessment areas and East Coast are smaller than those from other assessment areas. In the South East, most lobsters landed are between 80 and 100 mm CL and there are very few larger animals (>100 mm CL) (Figure 89). Both long term LFDs (Figure 87) and the average size of the largest 20% individuals (Figure 88) have remained fairly stable in the last thirty years, suggesting that there have been only relatively small changes in fishing mortality over this time. LCA indicates that the lobsters in the South East (both males and females) are being growth overfished (Figure 90). The fishery for the male lobsters in particular would benefit from a reduction in effort. However, it should be noted that the growth parameters assumed in this assessment are the same as those applied to lobsters in the other areas. This may not be appropriate if individuals in the South East are slower growing and attain smaller sizes. The use of inappropriate growth parameters in the LCA could overestimate the magnitude of growth overfishing.

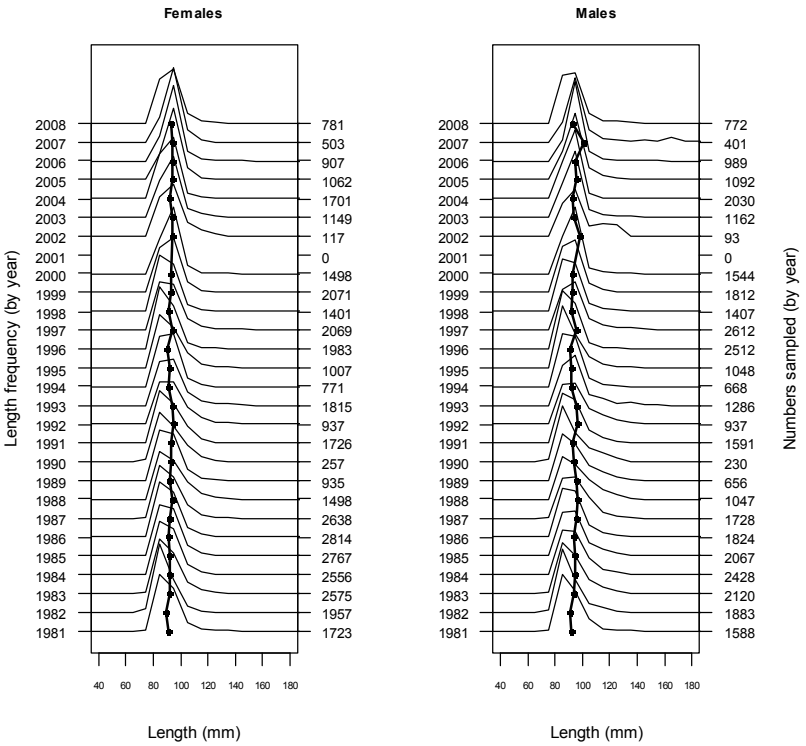

Figure 87: Time series of length frequency for lobster in the South East assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

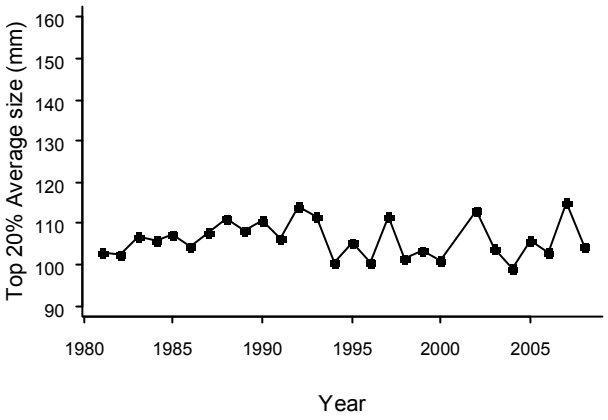

Figure 88: Lobster average size of the top 20% individuals sorted by size in the South East assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

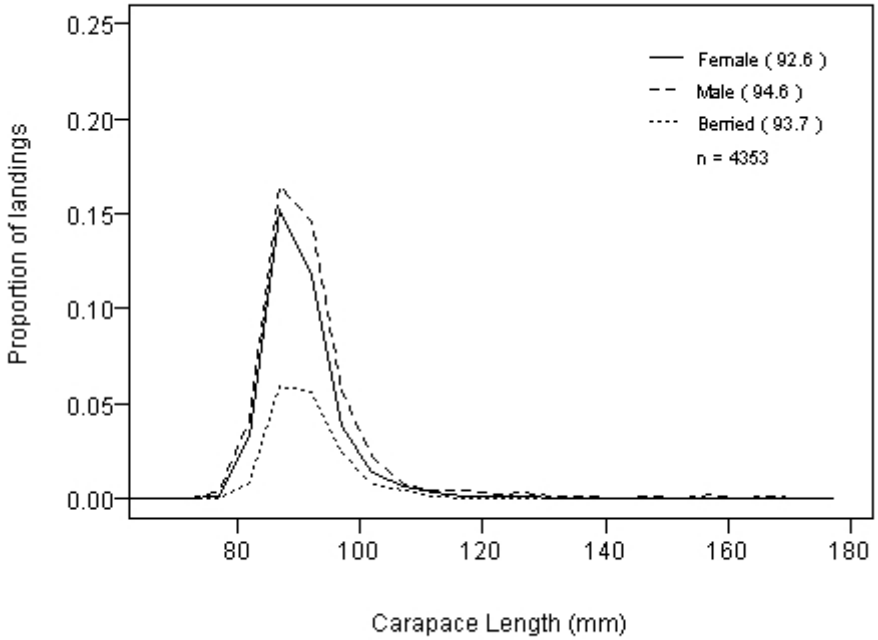

Figure 89: Lobster carapace length (mm) frequency histogram for the South East assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

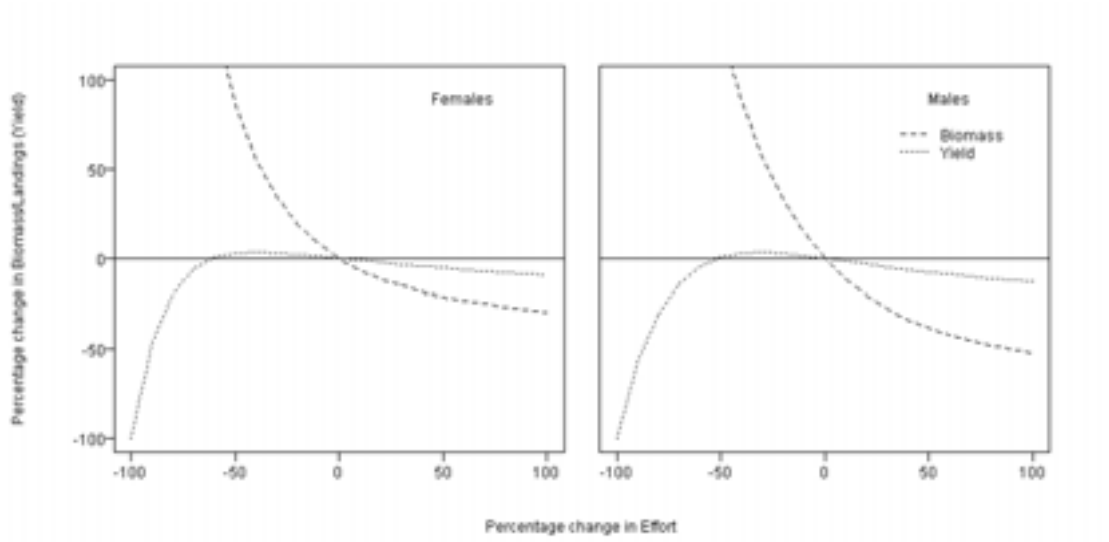

Figure 90: Biomass and Yield-per-recruit predictions for given changes from current effort for lobster in the South East assessment area, data from 2006-2008. See Figure **1** for area locations.

3.2.10 South Minch

The South Minch assessment area, which includes the ports of Oban and the south of Skye, supports an important mixed creel fishery. The lobster landings are greater over the summer and peak in July and August, while the brown crab and velvet crab landings increase towards the end of the year (Figure 91).

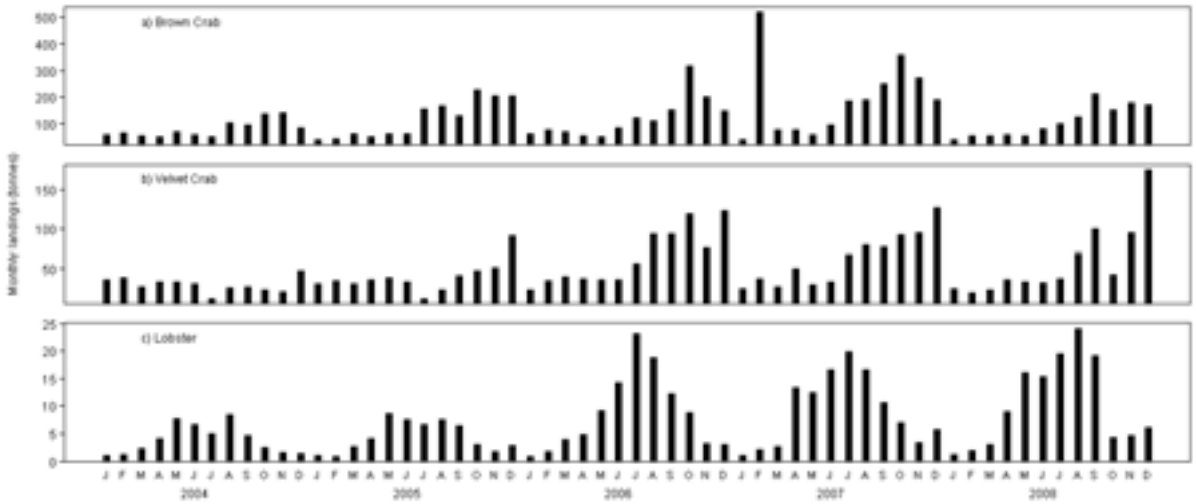

Figure 91: Monthly landings of brown crab, velvet crab and lobster for the South Minch assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

In the 1970s and 80s brown crab in the South Minch area was a by-catch of the more profitable lobster fishery (Mason *et al*., 1983) and crab stocks were considered to be under exploited. However, today there is a sizeable brown crab fishery in the area which accounted for up to 18% of the total Scottish landings between 2006 and 2008 (Table 4). Reported landings from the South Minch peaked in this area in 2007 at 2,150 tonnes, but dropped by 47% in 2008 to 1,140 tonnes. Two thirds of the crabs in the sampled landings from the area were females. Sampled males and females were similar in size (Figure 94). The long term LFDs and the mean size of the largest 20% individuals are shown in Figure 92 and Figure 93, respectively. There are no obvious trends in the mean sizes over the 30 year time period. The size frequencies show occasional modes which may be linked to strong year classes. However, given the relatively low sampling levels in this area, it seems more likely that these (and the apparent inter-annual variability in the mean sizes) are due to sampling error. LCA indicates that both male and female brown crabs are being fished above F_{MAX} - the level consistent with maximum long term yield-per-recruit. Any increase in effort would decrease the long term yield-per-recruit (Figure 95).

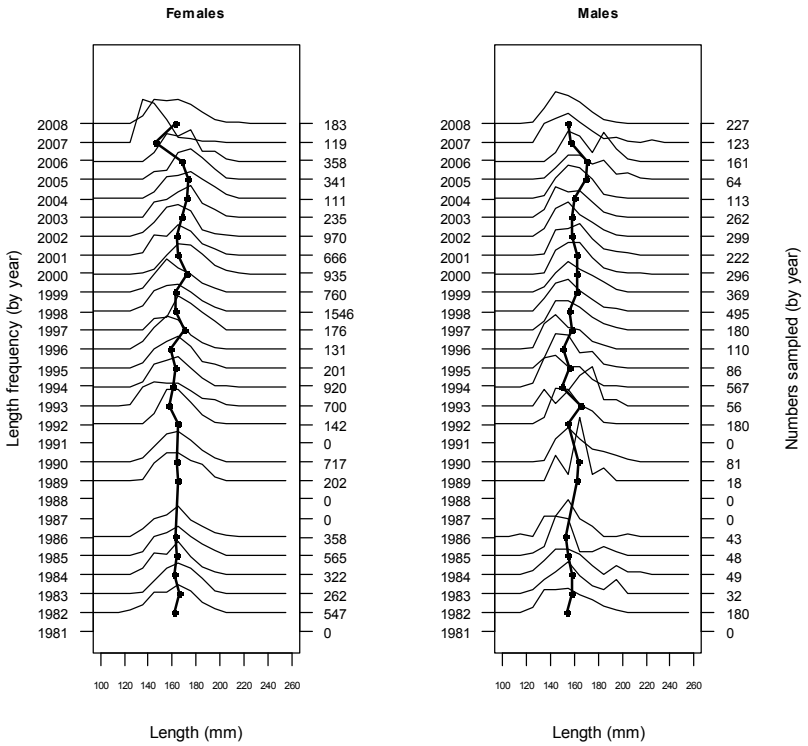

Figure 92: Time series of length frequency for brown crab in the South Minch assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

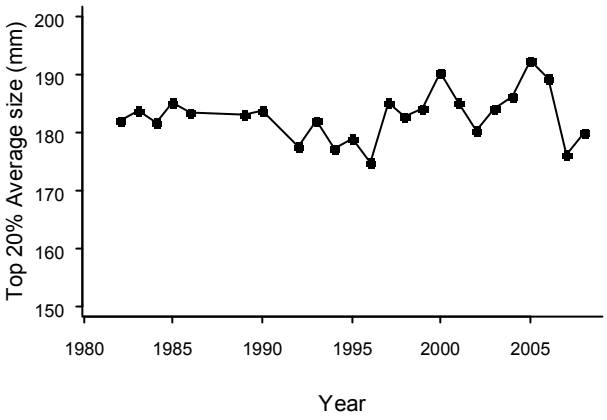

Figure 93: Brown crab average size of the top 20% individuals sorted by size in the South Minch assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

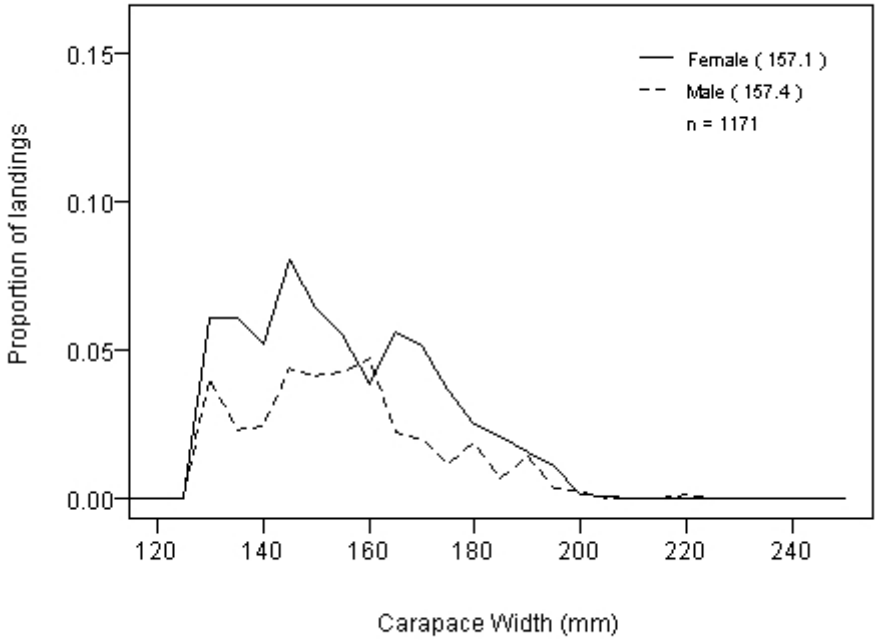

Figure 94: Brown crab carapace width (mm) frequency histogram for the South Minch assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

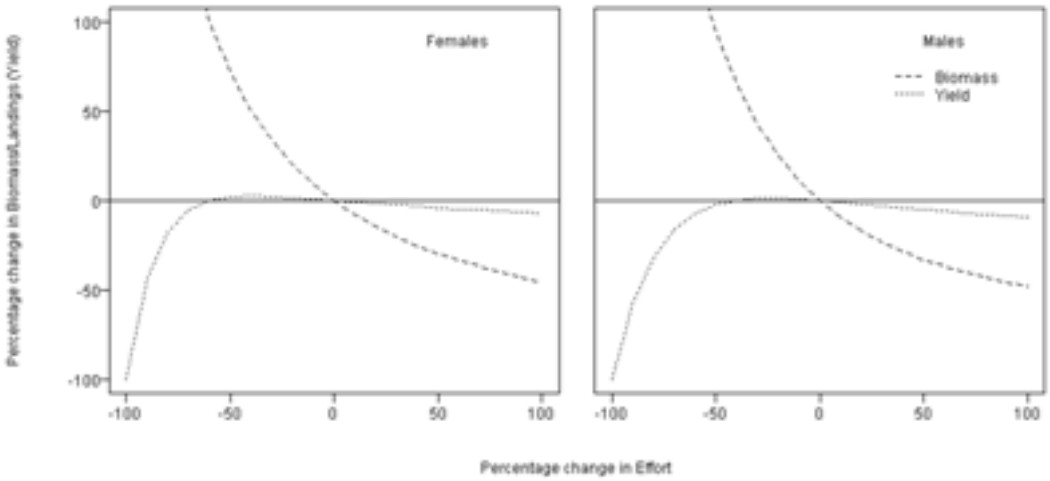

Figure 95: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the South Minch assessment area, data from 2006-2008. See Figure 1 for area locations.

Velvet Crab

The South Minch is one of the main fishery areas for velvet crab accounting for approximately 22% of the total Scottish landings in recent years. Between 2006 and 2008, relatively low landings were reported in the first quarter of the year; landings of 20 to 40 tonnes per month between January and March, increased steadily throughout the rest of the year to peak at over 100 tonnes in December each year (Figure 91). The market sampling data for velvet crabs in the South Minch assessment area shows that males represent around 76% of landings (Figure 98). No marked changes in the long term LFDs were identified for velvet crab over the last twenty years (Figure 96). After a long period of stability (1981-2002), the average size of the largest 20% individuals has been more variable in recent years (Figure 97). This may reflect an increase in fishing mortality, but could also be due to changing fishing practices or due to sampling variability. LCA indicates that fishing mortality is above F_{MAX} for both males and females. A reduction in effort would increase the male yield-per-recruit by a few percent of the current level (Figure 99).

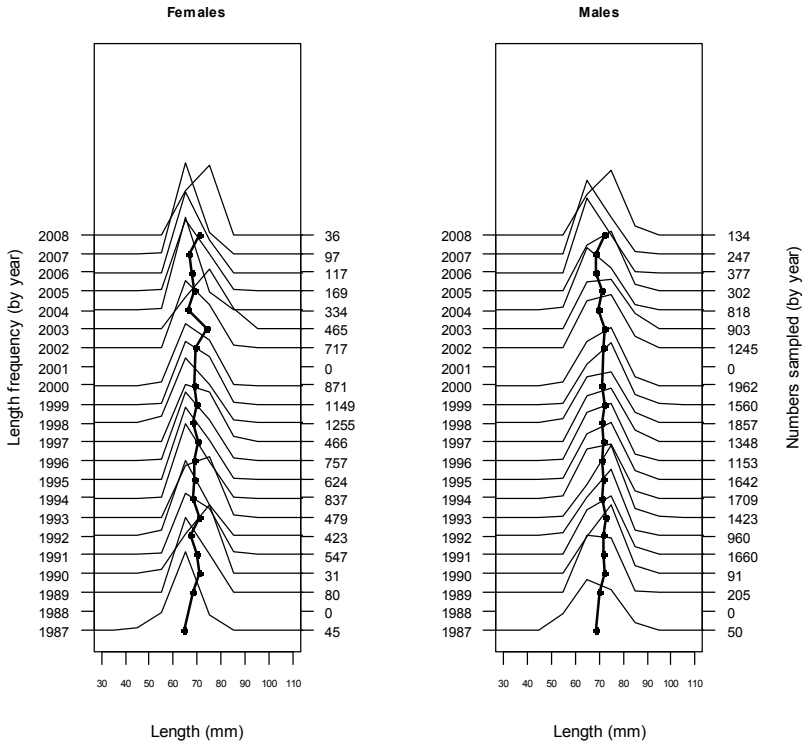

Figure 96: Time series of length frequency for velvet crab in the South Minch assessment area between 1987 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

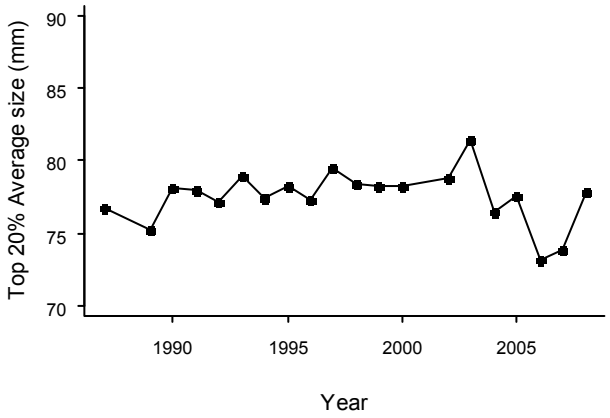

Figure 97: Velvet crab average size of the top 20% individuals sorted by size in the South Minch assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

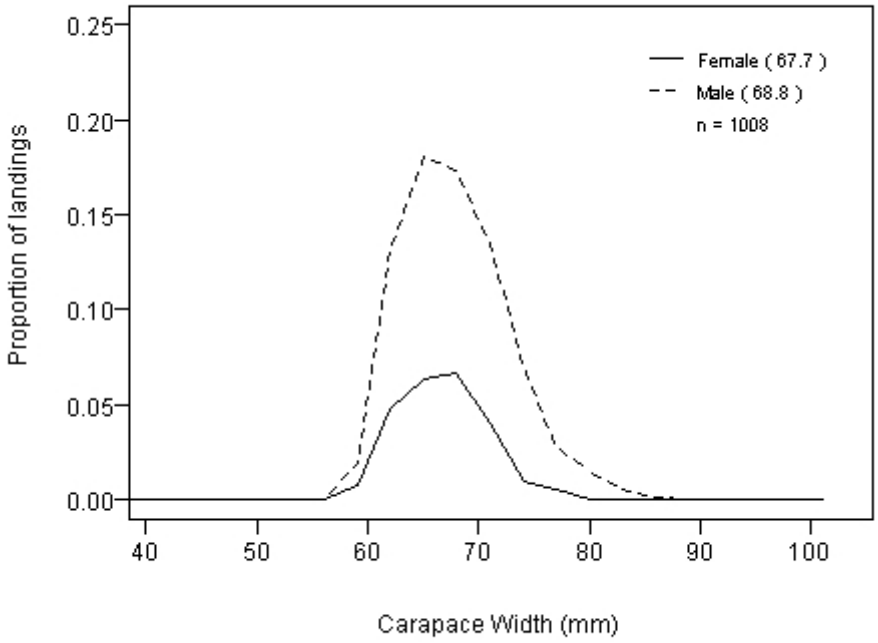

Figure 98: Velvet crab carapace width (mm) frequency histogram for the South Minch assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 3 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

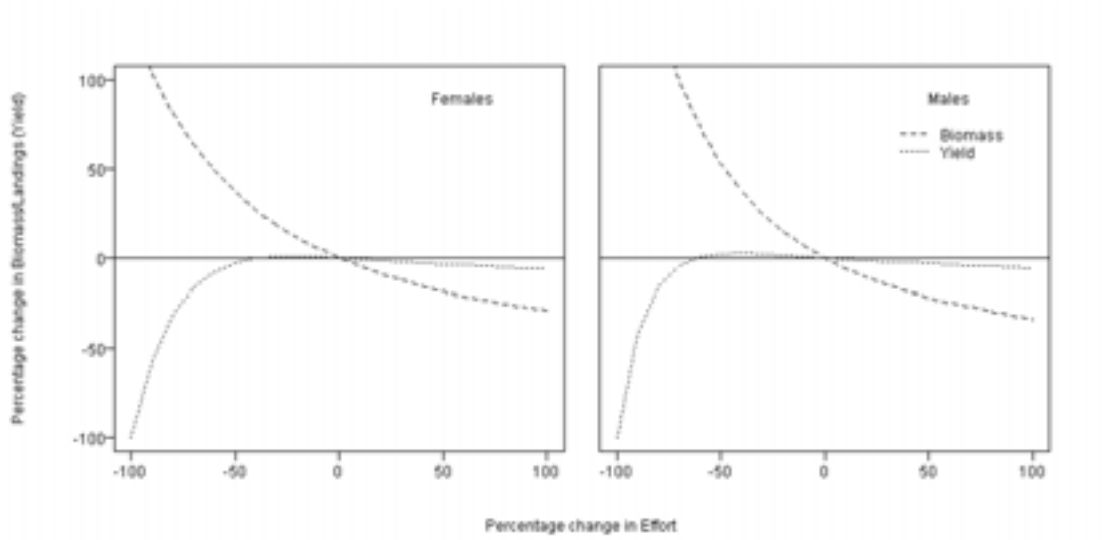

Figure 99: Biomass and Yield-per-recruit predictions for given changes from current effort for velvet crab in the South Minch assessment area, data from 2006-2008. See Figure 1 for area locations.

Lobster

Lobster landings from the South Minch are seasonal and peak during the summer months (Figure 91). The size structure of the sexes was similar with 64% of landed lobsters being males (Figure 102). The long term LFDs and the largest 20% individuals are shown in Figure 100 and Figure 101, respectively. No clear pattern based on size changes could be identified for lobster over the last decade. Sample sizes are low and therefore the pronounced decline (and subsequent increase) in sampled mean size observed at the beginning of the time series may not be indicative of trends in the population (or landings) as a whole. Given the low sampling level for this area between 2006 and 2008, LCAs were not carried out for lobster stocks in the South Minch.

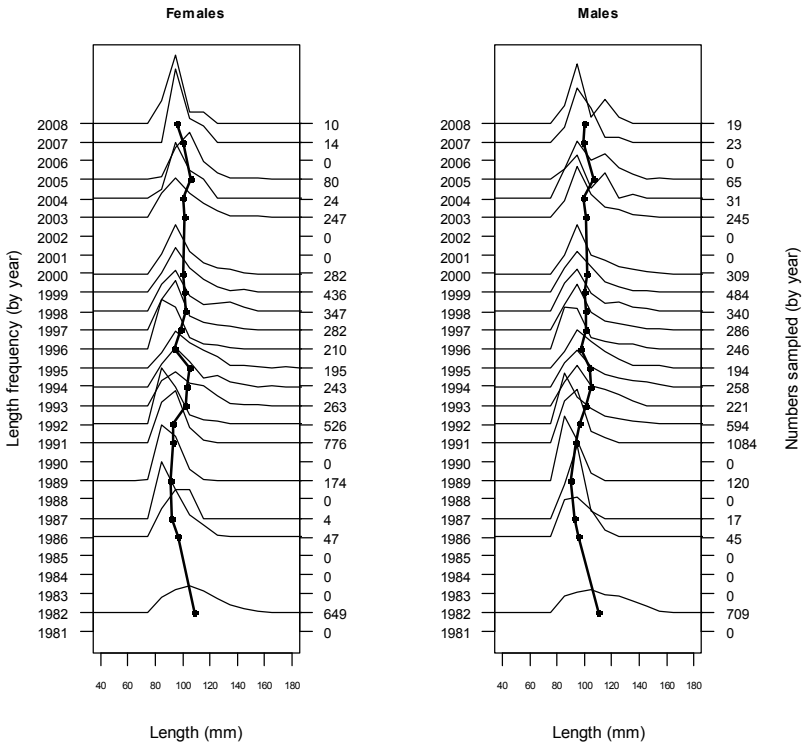

Figure 100: Time series of length frequency for lobster in the South Minch assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

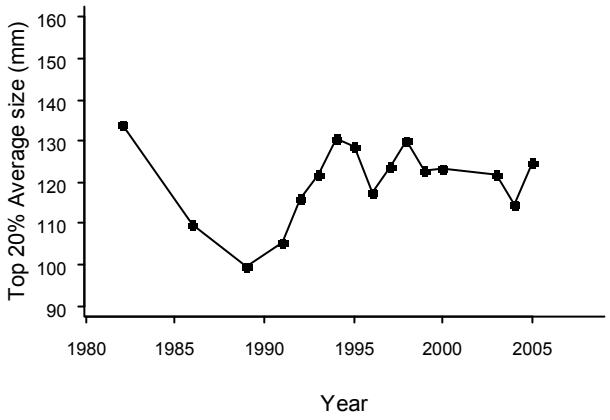

Figure 101: Lobster average size of the top 20% individuals sorted by size in the South Minch assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

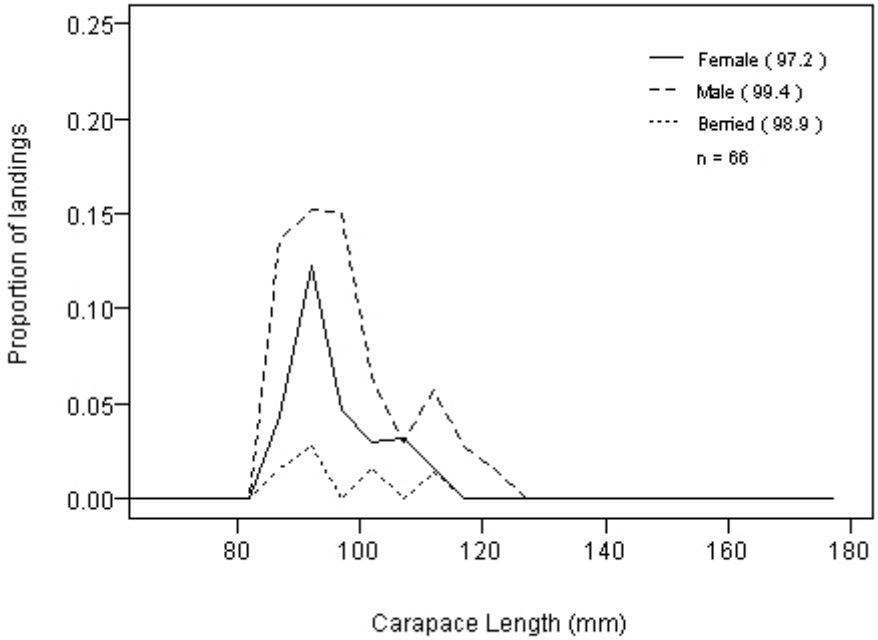

Figure 102: Lobster carapace length (mm) frequency histogram for the South Minch assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

3.2.11 Sule

Sule Stack, Rona and Sule Skerry are volcanic stacks located in the North Atlantic off the north coast of Scotland, 66 km west of Orkney. The brown crab fishery in this area is a relatively recent development. Landings from this area have been recorded since 1996 and MSS length frequency sampling has been carried out since 1998. In 2004, an EU regulation (Council Regulation (EC) No. 2287/2003), which prohibited all other fishing except with creels and pots in an area within the Sule assessment area known as the 'Windsock' area, was introduced. The regulation, part of cod recovery measures, has had the additional effect of ensuring that static fishing gear set in this area is not disturbed by trawlers and has been very favourable to the crab fishermen. The Sule area is fished almost exclusively by vivier crabbers and landings are made weekly to larger ports such as Scrabster and Ullapool. There were very few velvet crab landings from Sule reported between 2006 and 2008. It is unlikely that this species is present in great quantities. Lobster landings from Sule are modest and only represent a small proportion of the Scottish total (less than 1%).

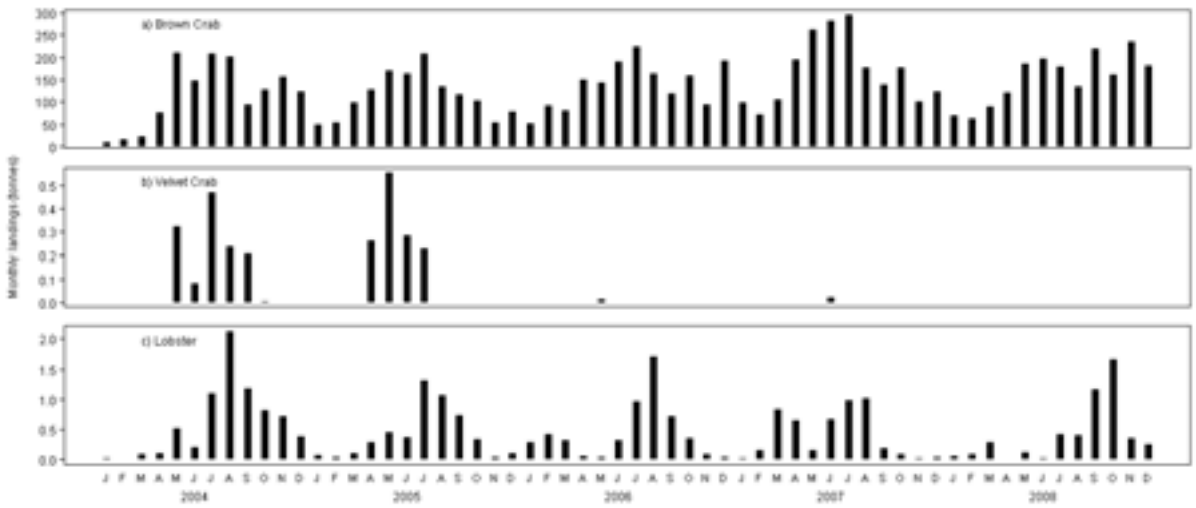

Figure 103: Monthly landings of brown crab, velvet crab and lobster for the Sule assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

Brown Crab

Brown crab landings from Sule have increased steadily since the fishery began and reached their highest level of over 2,000 tonnes in 2007 (Figure 3). Little is known about this offshore crab stock, but it is possible that it is a previously unexploited extension of the inshore stock. Landings peak during the summer months (Figure 103), when the weather is more reliable and the seas are calmer. Around 73% of crabs sampled from the Sule area were females (Figure 106). This may be due to migratory patterns of the female crab and the seasonality of the fishery, which is prosecuted during months when female crabs are more active. In the second quarter, sampling showed that males and females were landed in approximately equal proportions whereas in the first and third quarters the female proportion increased to over 80%. Sampled data for brown crab in the Sule area were not available for the fourth quarter in the 2006-2008 period. Both the long term LFDs (Figure 104) and the average size of the largest 20% individuals (Figure 105) showed no major size changes over the last ten years. LCA of the Sule brown crab indicates that crab (both male and female) were fished close to F_{MAX} (Figure 107) between 2006 and 2008 and predictions indicate any increase in effort would reduce the long term yield-per-recruit.

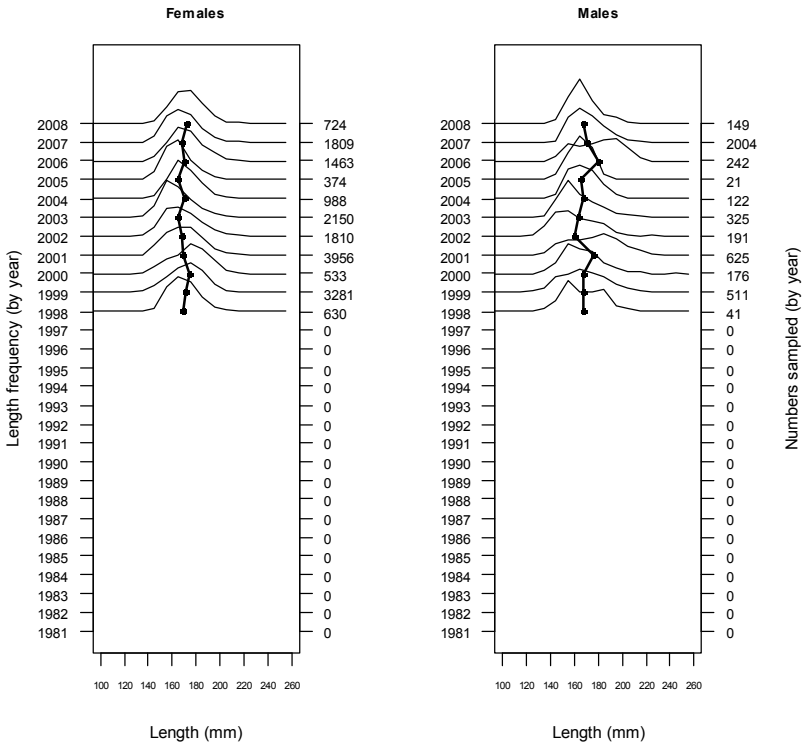

Figure 104: Time series of length frequency for brown crab in the Sule assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

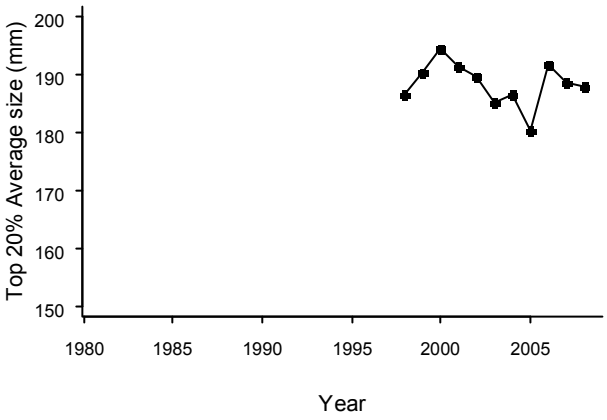

Figure 105: Brown crab average size of the top 20% individuals sorted by size in the Sule assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

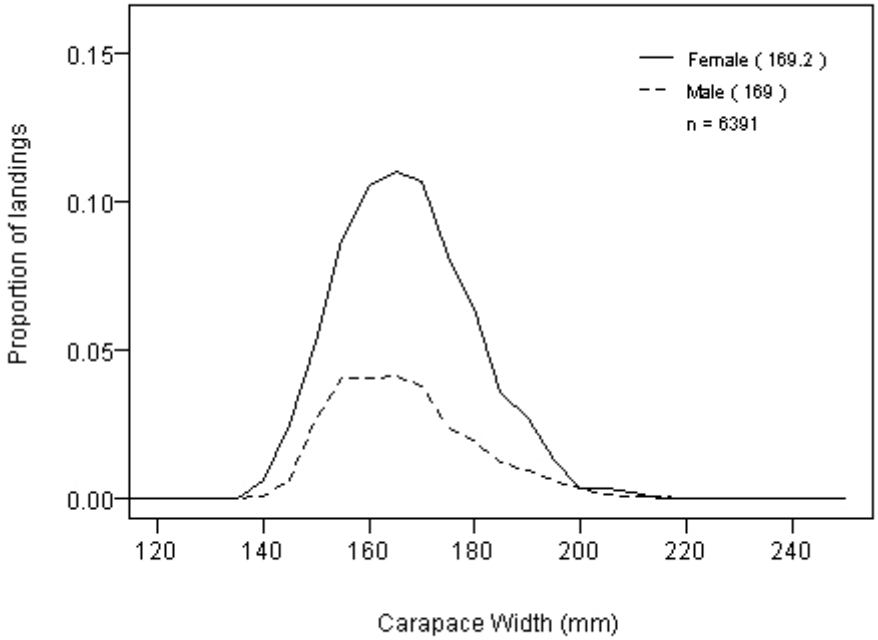

Figure 106: Brown crab carapace width (mm) frequency histogram for the Sule assessment area. Carapace width frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean widths. n= numbers measured.

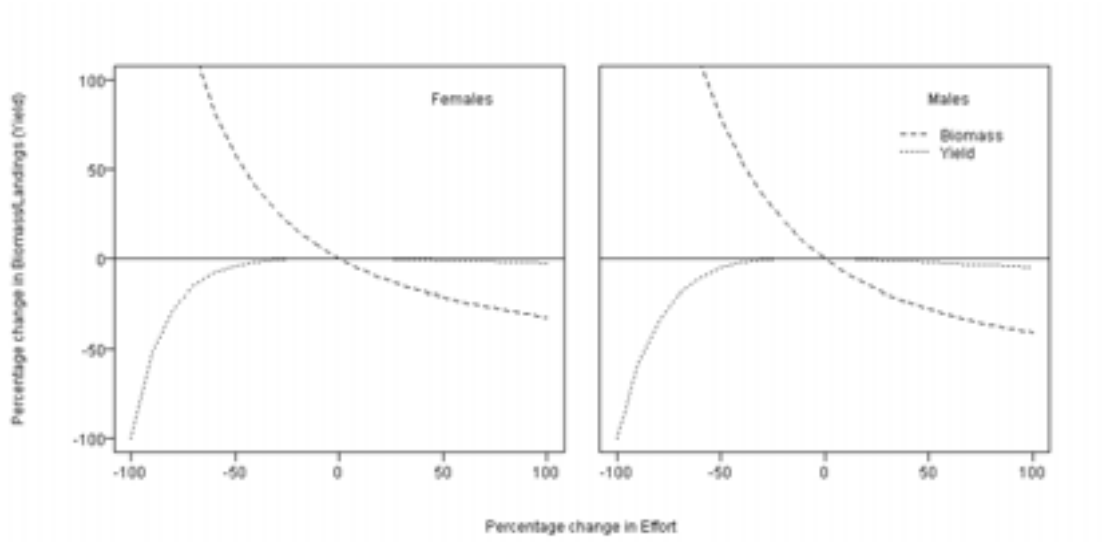

Figure 107: Biomass and Yield-per-recruit predictions given changes from current effort for brown crab in the Sule assessment area, data from 2006-2008. See Figure 1 for area locations.

Velvet Crab

Velvet crab is not targeted in this area and landings are very low and are incidental to the brown crab fishery.

Lobster

Small quantities of lobster (under 2 tonnes/month) are landed from the Sule area; this is likely to be as incidental catch of the brown crab fishery. The seasonality of landings was similar to those from the brown crab from this region, with the highest landings by weight occurring in July and August (Figure 103).

3.2.12 Ullapool

The main ports of the Ullapool assessment area include Ullapool, Lochinver and Kinlochbervie. Monthly landings of all species are modest and the area's landings made up approximately 2 to 3% of the national total for each species (Table 4). Landings varied seasonally, with the largest landings of velvet crabs and lobsters occurring between July and October each year. Brown crab landings tend to increase towards the winter months (Figure 108).

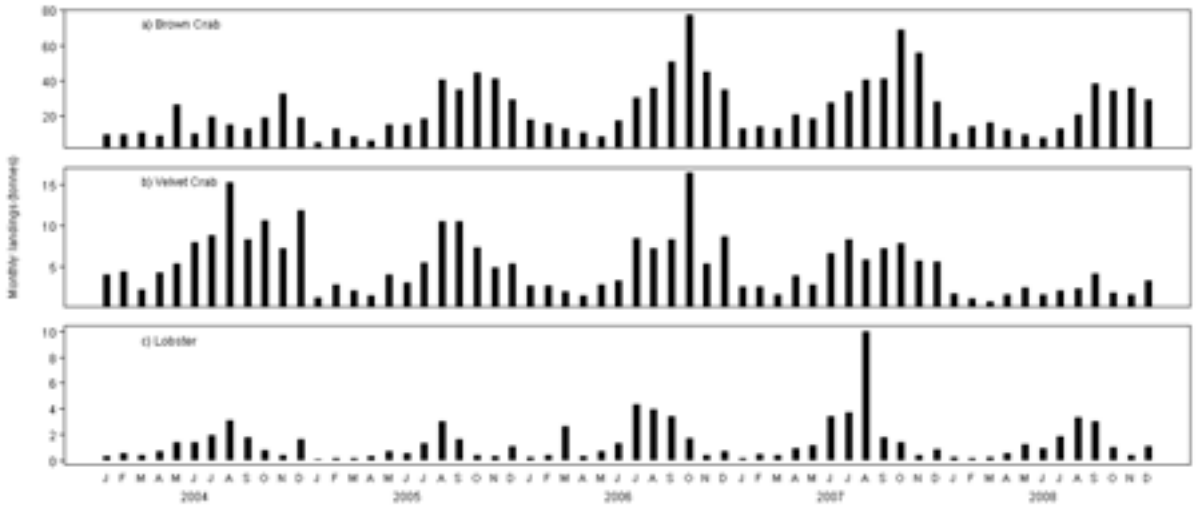

Figure 108: Monthly landings of brown crab, velvet crab and lobster for the Ullapool assessment area from 2004-2008. Data are from Fisheries Management Database. See Figure 1 for area locations.

For both brown and velvet crab in this area, market sampling data were insufficient to conduct LCAs or investigate trends in size structure.

Lobster

The length frequency distributions show more males than females in the landings and that males are larger than females (Figure 111). Figure 109 shows that sampling has been sporadic and for that reason it seems unlikely that the trends in the largest 20% individuals are a particularly reliable indicator of trends in sizes landings or in population (Figure 110). Previously, there were insufficient data to perform LCAs (Mill *et al.*, 2009). However, increased sampling of lobster from the area in 2006 and 2007 allowed LCAs to be carried out. These indicate that females are being fished below F_{MAX} whereas males are being fished above F_{MAX} (Figure 112).

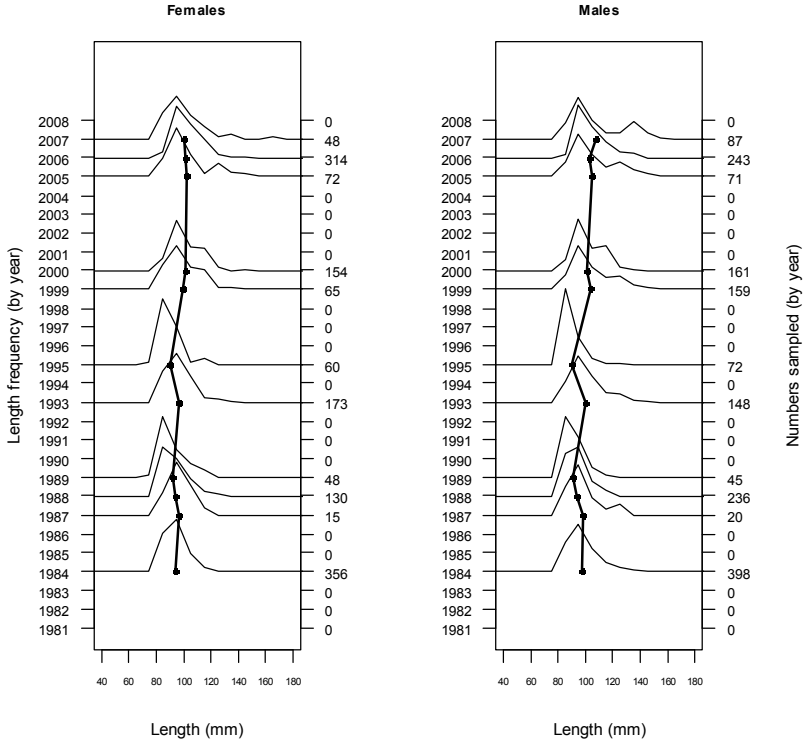

Figure 109: Time series of length frequency for lobster in the Ullapool assessment area between 1981 and 2008 from MSS market sampling data. The dotted vertical line represents the average size for each year.

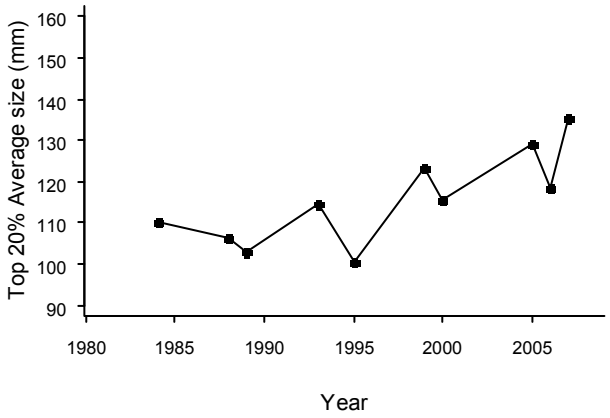

Figure 110: Lobster average size of the top 20% individuals sorted by size in the Ullapool assessment area in the period 1981-2008. Sexes were combined (a minimum of 50 individuals was used each year to calculate average sizes). Data from MSS market sampling programme.

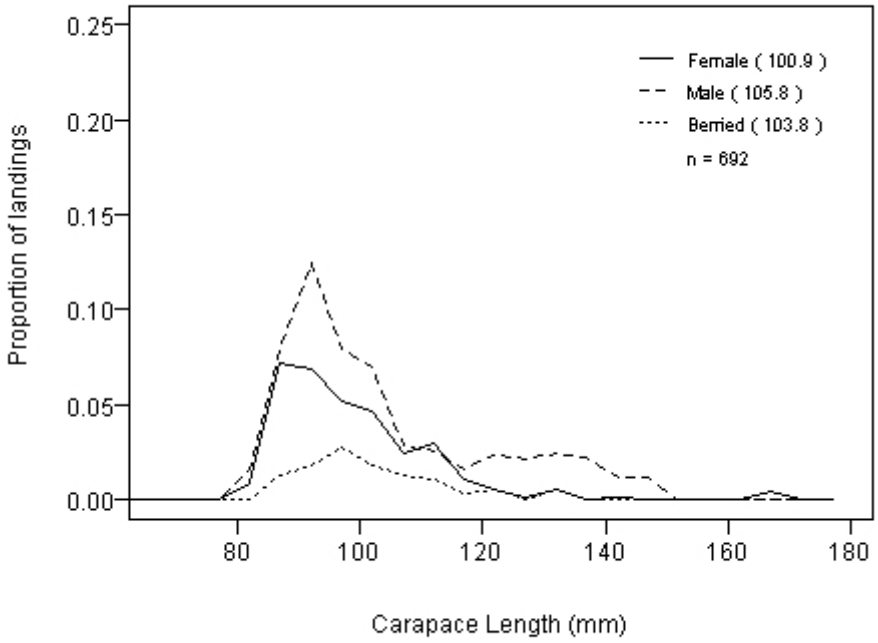

Figure 111: Lobster carapace length (mm) frequency histogram for the Ullapool assessment area. Carapace length frequency data have been raised to the official landings data for this area and averaged over the period 2006-2008. The data presented are aggregated by 5 mm increments and shown as a proportion of the total landings. Numbers in brackets are mean lengths. n= numbers measured.

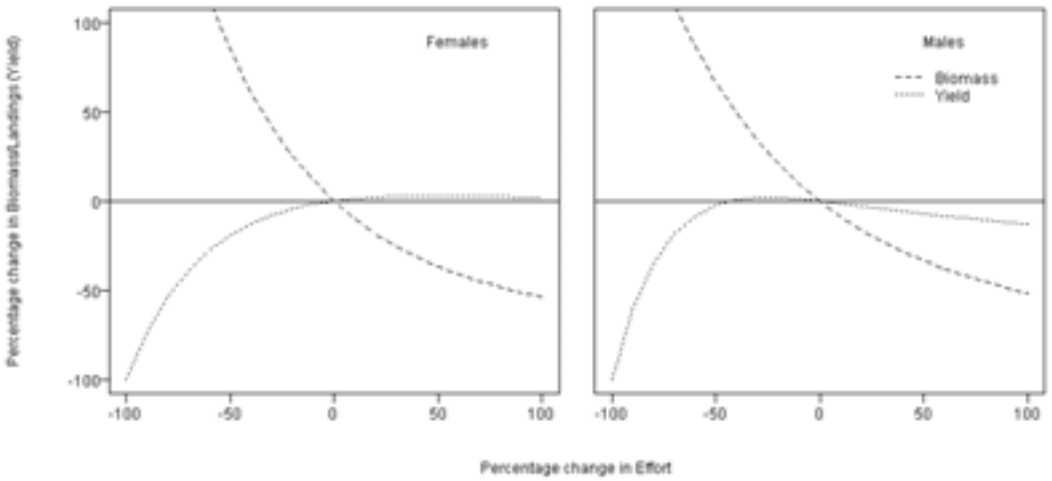

Figure 112: Biomass and Yield-per-recruit predictions for given changes from current effort for lobster in the Ullapool assessment area, data from 2006-2008. See Figure 1 for area locations.

3.3 Summary Tables

Tables 5, 6 and 7 summarize LCA statistics, $F_{0.1}$, F_{MAX} and F_{bar} (mean fishing mortality averaged across the interquartile length range) for the three assessed species by area and sex. Tables 8, 9 and 10 summarize some general stock details such as landings, sex ratio and mean size for the three assessed species by area and sex.

Table 5

LCA statistics for brown crab ($F_{0.1}$, F_{MAX} and F_{bar}) by area and sex.

Area Name	Sex	$F_{0.1}$	F_{MAX}	F_{bar}
Clyde	Males	0.23	0.38	0.56
Clyde	Females	0.10	0.18	0.35
East Coast	Males	0.20	0.36	0.54
East Coast	Females	0.13	0.29	0.33
Hebrides	Males	0.16	0.31	0.35
Hebrides	Females	0.16	0.38	0.47
Mallaig		Not assessed		
North Coast	Males	0.20	0.36	0.62
North Coast	Females	0.22	0.45	0.58
Orkney	Males	0.17	0.31	0.48
Orkney	Females	0.17	0.40	0.46
Papa		Not assessed		
South East	Males	0.20	0.34	0.52
South East	Females	0.16	0.29	0.59
Shetland	Males	0.34	0.79	1.19
Shetland	Females	0.41	1.41	0.66
South Minch	Males	0.19	0.34	0.44
South Minch	Females	0.13	0.25	0.42
Sule	Males	0.22	0.43	0.48
Sule	Females	0.17	0.45	0.48
Ullapool		Not assessed		

Table 6

LCA statistics for velvet crab ($F_{0.1}$, F_{MAX} and F_{bar}) by area and sex.

Area Name	Sex	$F_{0.1}$	F_{MAX}	F_{bar}
Clyde	Males	0.11	0.18	0.60
Clyde	Females	0.16	0.29	0.63
East Coast	Males	0.10	0.26	0.28
East Coast	Females	0.10	0.23	0.26
Hebrides	Males	0.10	0.33	0.25
Hebrides	Females	0.11	0.27	0.31
Mallaig		Not assessed		
North Coast		Not assessed		
Orkney	Males	0.05	0.11	0.28
Orkney	Females	0.08	0.15	0.38
Papa		Not assessed		
South East	Males	0.10	0.29	0.26
South East	Females	0.10	0.21	0.24
Shetland	Males	0.29	1.78	0.66
Shetland	Females	0.48	1.38	0.88
South Minch	Males	0.17	0.33	0.58
South Minch	Females	0.23	0.42	0.54
Sule		Not assessed		
Ullapool		Not assessed		

Table 7

LCA statistics for lobster ($F_{0.1}$, F_{MAX} and F_{bar}) by area and sex.

Area Name	Sex	$F_{0.1}$	F_{MAX}	F_{bar}
Clyde	Males	0.14	0.23	0.48
Clyde	Females	0.18	0.32	0.45
East Coast	Males	0.16	0.25	0.56
East Coast	Females	0.16	0.29	0.46
Hebrides	Males	0.15	0.25	0.34
Hebrides	Females	0.19	0.36	0.23
Mallaig		Not assessed		
North Coast		Not assessed		
Orkney	Males	0.17	0.27	0.44
Orkney	Females	0.17	0.30	0.24
Papa		Not assessed		
South East	Males	0.22	0.33	0.49
South East	Females	0.24	0.43	0.72
Shetland	Males	0.18	0.28	0.29
Shetland	Females	0.20	0.31	0.45
South Minch		Not assessed		
Sule		Not assessed		
Ullapool	Males	0.10	0.16	0.21
Ullapool	Females	0.20	0.37	0.25

Table 8

Brown crab general stock details by area and sex.

Area	Landings (t)			Sex ratio (% males) 2006-2008	Mean size (mm) Carapace width 2006-2008	
	2006	2007	2008		M	F
Clyde	198	250	213	42	153.6	161.8
East Coast	830	884	867	60	156.4	164.2
Hebrides	2279	2340	1738	23	165.3	169.0
Mallaig	8	67	32	-	-	-
Papa Bank	838	798	764	13	173.7	168.3
North Coast	436	514	349	16	158.2	160.4
Orkney	1468	1555	1187	30	160.8	166.1
Shetland	641	522	567	47	155.5	162.1
South East	274	282	325	72	151.9	150.9
South Minch	1316	2150	1140	37	157.4	157.1
Sule	1663	2026	1836	27	169.0	169.2
Ullapool	358	376	242	20	159.9	164.4

Table 9

Velvet crab general stock details by area and sex.

Area	Landings (t)			Sex ratio (% males) 2006-2008	Mean size (mm) Carapace width 2006-2008	
	2006	2007	2008		M	F
Clyde	176	163	163	80	69.0	68.3
East Coast	298	427	348	81	75.1	72.3
Hebrides	294	319	245	67	75.2	72.5
Mallaig	34	21	2	-	-	-
Papa Bank	6	2	3	-	-	-
North Coast	8	4	3	-	-	-
Orkney	844	938	872	56	73.7	70.5
Shetland	100	166	290	-	-	-
South East	153	198	181	77	72.8	70.4
South Minch	617	595	540	76	68.8	67.7
Sule	-	-	-	-	-	-
Ullapool	69	61	25	-	-	-

Table 10

Lobster general stock details by area and sex.

Area	Landings (t)			Sex ratio (% males) 2006-2008	Mean size (mm) Carapace length 2006-2008		
	2006	2007	2008		M	F	B
Clyde	19	17	22	54	99.0	94.0	98.2
East Coast	87	130	147	50	94.8	92.3	98.0
Hebrides	168	204	161	54	109.2	103.4	110.0
Mallaig	1	1	3	-	-	-	-
Papa Bank	7	8	7	47	116.8	117.2	122.9
North Coast	15	14	15	61	110.7	106.9	104.2
Orkney	122	133	139	48	100.6	96.3	104.6
Shetland	9	14	20	-	-	-	-
South East	136	180	204	47	94.6	92.6	93.7
South Minch	95	102	111	64	99.4	97.2	98.9
Sule	5	5	5	-	-	-	-
Ullapool	27	58	66	55	105.8	100.9	103.8

4. Discussion

Brown crab continues to be the most important species, both in terms of total weight and value at first sale, in the mixed crab and lobster fisheries around Scotland. The data presented in this report show that there have been some changes in the spatial distribution of landings with increased landings from the Clyde, East Coast and Sule over 2006 to 2008. Although the Hebrides and the South Minch remain two of the most important brown crab fishery areas, the landings from these areas declined substantially in 2008. This may be related to depressed market prices and reduced effort rather than any change in the abundance of the stock. Total landings of velvet crab have remained stable in recent years. Increases in reported landings from traditionally less important areas such as the East, South East and Shetland have coincided with small decreases elsewhere. Lobster landings, although still much lower than those of brown and velvet crabs have more than doubled since 2001 with the East, South East, Hebrides, Orkney and South Minch areas all contributing to this increase.

4.1 Assessment Results

Brown crab:
Brown crab market sampling data show spatial differences in the sex composition of the landings. In the Orkney, North Coast, Sule, and Hebrides assessment areas, over 70% of the sampled brown crab landings were female. In contrast the sex ratios of the landings in the East Coast and South East areas are biased towards males: 60-70% of the landings sampled from these assessment areas were male whereas sex ratios in landings from the other areas were approximately equal. The sampled data show that brown crabs from the Hebrides, North Coast and offshore areas tend to be larger (over 160 mm in the North Coast up to an average of 170 mm in Sule) than those from the South East (mean CW ca. 152 mm). Crabs in the South East assessment areas were also noted as being smaller than the national average in previous reports (Kinnear, 1988). Assessments based on these data (using LCA) were carried out for nine out of the twelve assessment areas. Table 5 shows the LCA estimate of fishing mortality (over 2006 to 2008) in relation to the reference points $F_{0.1}$ and F_{MAX} for those areas where sufficient sampling data were available to carry out an assessment. Stocks in most of the areas remain growth overfished to some extent, especially among the males. For the Hebrides and the East Coast the assessment results show an improvement compared to those reported previously (Mill *et al*., 2009) with only male East Coast crab growth overfished and both sexes of Hebrides brown crab fished at around $F_{MAX.}$

Velvet crab:
For velvet crabs, the market sampling data show that males were more common, made up 56-81% of the landings sampled, and were slightly larger than the females. In all areas the

mean CW of sampled landings was greater than the minimum landings size of 65 mm with larger crabs being found in the East Coast and Hebrides. Velvet crab assessments based on these data (using LCA) were carried out for seven assessment areas (Table 6). In the Hebrides, Shetland, East Coast, and South East, the estimated fishing mortality (2006-2008) is below or just above F_{MAX} whilst velvet crab stocks in Clyde, Orkney and South Minch are being fished at levels significantly above F_{MAX}. The results have not changed since the previous assessment presented in Mill *et al*., 2009 (based on data from 2002-2005) except for the Clyde where previously only the males were fished above F_{MAX}.

Lobster:
Lobster market sampling data from 2006-2008 suggest that male and female lobsters were generally landed in equal proportions and that between 15-30% of landings in the assessed areas were berried females. There are significant differences in mean size in the sampled landings between areas with lobsters from the North Coast and Hebrides being significantly larger than those from the South East and East Coast areas. The LCA assessments carried out for seven assessment areas (Table 7), indicate that both male and female lobsters in the Clyde, East Coast and South East were all being fished above F_{MAX} over the years 2006 to 2008 and any increase in fishing effort would result in a long term decrease in yield. In the other stocks, males are estimated to be growth-overfished whilst females are being fished at or just below F_{MAX} (except Shetland where females are being fished slightly above F_{MAX}).

4.2 Comments on the Assessment and Data Quality

Landings data:
From the range of stock assessment tools available, LCA is one of the least data intensive and LCA and yield-per-recruit models are often the preferred methods, or the only methods available, for assessing data-poor shellfish stocks. A major assumption of the LCA is that the landings length frequency distribution is representative of the fishery removals from a single cohort of individuals throughout its life. However, since the length frequencies are derived from a single year of sampling, rather than from a single cohort, then this assumption is only true if the population is in a steady state or at equilibrium i.e. that recruitment and exploitation rate are constant. Landings data from most of the Scottish assessment areas tends to fluctuate which may reflect year to year variation in recruitment or fishing effort. A three year average of the length frequency data is used in order to limit the effects of these variations although systematic changes in exploitation rate or recruitment over this three year period could still result in biased estimates of fishing mortality.

Biological parameters:
In addition to adequate landings length frequency distribution data, LCA also requires estimates of other biological parameters, including von Bertalanffy growth parameters and natural mortality. LCA is very sensitive to these parameters and the choice of input parameters may critically influence the results obtained (Lai and Gallucci, 1988; Jones, 1990), such as the perception of the state of the stock, in terms of the position of the current

exploitation rate in relation to F_{MAX}. Preliminary results from a sensitivity analysis study carried on LCA examining a range of input parameters (Mesquita, unpublished) showed that natural mortality (*M)* has the greatest effect on the shape of the relative yield per recruit curve. Using lower values for *M* results in a more pessimistic stock assessment with current fishing mortality estimated to be higher in relation to F_{MAX} (or vice-versa). This could potentially be one of the reasons for the disparity in the results obtained for female velvet crab in Shetland when compared to Orkney, two stocks with relatively similar length frequency distributions. At Orkney, females are estimated to be growth overfished, whereas in Shetland, where *M* is considered to be higher (0.576 compared to 0.1 elsewhere), they are estimated to be fished below F_{MAX}.

The values of the von Bertalanffy growth parameters (*K* and L_∞) also affect the shape of the relative yield per recruit curve and estimation of the value of F in relation to $F_{MAX.}$ Using growth model parameters which result in growth rates which exceed the true growth rate (i.e. using values of *K* and L_∞ which are too large) results in the current exploitation rate (F) being over-estimated in LCA and could lead to the erroneous conclusion that a stock is growth-overfished (and vice-versa). Currently, the same biological parameters, those which were used in previous assessments (Chapman, 1994; Mill *et al*., 2009) are applied across all regions (except Shetland). Differences in size composition across areas, particularly the relatively small size of brown crab and lobster in the South East compared to the north and west, suggest that area specific values may be more appropriate and it is possible that the extent of growth overfishing of brown crab and lobster in the East Coast and South East may be overestimated. A re-evaluation of the parameters used in LCA would be extremely useful but it would involve a large scale tagging project using tags which could be reliably retained on moult, with seasonal measurements of length and weight.

Other factors:

Given that LCA provides only long term equilibrium predictions, it is usually advisable to complement the results of LCA with additional data which can provide temporal information on trends in abundance, typically catch per unit effort data or exploitation rate. Effort data in terms of numbers of creels fished are not currently available, precluding calculation of catch per unit effort in these fisheries. In an attempt to gain additional information on variation in year class strength and fishing mortality from the data available, we explored for the first time trends in landings length frequencies and mean size of largest 20% of individuals. In a number of well sampled areas, trends are apparent which could be associated with changing exploitation rate or recruitment. For example, brown crab in the Orkney area and velvet crab in the Hebrides area both show an increase in the average size of the largest individuals over the time series which could be related to reduced fishing mortality. These areas also show sporadic occurrences of large numbers of small individuals in the length frequency data which could be due to increased recruitment in these years. In other areas (e.g. Shetland for brown crab or Orkney for velvet crab and lobster) the length frequency data appear relatively stable suggesting a stable stock and fishery. In many cases however, the data show significant inter-annual variability (although no trend) which could be due to low and erratic sampling. Trends could also reflect changes in fishing practices (e.g., retention

size) as well as changes in actual population size structure. This emphasizes the need for improved sampling and better information on fishing activity and fishers' behaviour to develop robust size based indicators for assessment purposes.

The conclusions in this report are all based on estimates of fishing mortality in relation to the reference point F_{MAX} i.e. whether or not a stock is growth overfished. Although LCA and yield-per-recruit analysis give an indication of current F relative to the fishing mortality required to optimize yield (from a particular cohort), it provides no indication of whether or not a stock is recruitment overfished (i.e. whether the stock is being fished at a sustainable rate). F_{MSY}, the fishing mortality which gives the maximum sustainable yield (high long term yield with low risk of stock depletion) is difficult to estimate. In addition to a yield-per-recruit curve, calculating F_{MSY} requires good estimates of recruitment and spawning stock biomass, which are not available for Scottish crab and lobster stocks. In cases where F_{MSY} cannot be estimated directly, proxy values based on per recruit analysis are often used. At a recent workshop held at ICES (ICES, 2010), it was advised that in cases where the peak in the yield per recruit curve was well defined and there is no evidence of poor recruitment at this level of fishing mortality, then F_{MAX} may be an appropriate proxy for F_{MSY}. In cases where the maximum is less well defined and the curve is more flat topped then $F_{0.1}$ (defined as the fishing mortality at which the slope of the yield per recruit curve is 10% of the slope at the origin) is likely to be a more appropriate proxy. For the purposes of consistency in this report, all discussion relates to the reference point F_{MAX} although $F_{0.1}$ values are also shown in Tables 5-7. In most areas around Scotland, the crab and lobster stocks are being fished at levels which result in yield per recruit values not far below the maximum. However, in some cases this fishing mortality is substantially above F_{MAX} making it more likely that these stocks (e.g. Orkney velvet crab) are recruitment overfished as well as growth overfished.

4.3 Data Gaps and Future Research Priorities

From the discussion above it is clear that there are a number of areas where research or enhanced data collection would improve Scotland's crab and lobster stock assessments. ICES has suggested a multiple indicator based approach (including LPUE, size-based indicators and recruitment indices) to the provision of advice on stock status for crab stocks as a potential way forward (ICES, 2009).

Fishing effort:
Currently, no useful measures of creel fishing effort are available from official log sheets which precludes the use of LPUE data as an indicator of abundance for the crab and lobster stocks around Scotland. Shetland is the only area for which effort data are available and routinely collected. The Shetland Regulating Order requires licensed fishers to return logbook information to the SSMO, detailing the catch location (at the 5 nm scale) and details of the number of creels or pots fished. The data acquired from this logbook scheme would appear transferable to other areas and would allow CPUE to be calculated in an appropriate manner (Leslie *et al.*, 2007). A recent EU project (Anon, 2010) investigated the use of voluntary logbooks with the aim of improving brown crab data collection and concluded that

although data collected as part of such schemes was generally 'fit for purpose', uptake of such schemes is typically low. In addition, the report concluded that for inshore vessels whose catch and effort are likely to be highly variable, high industry uptake would be required to ensure data precision and accuracy and that the data were representative of a particular geographic region. The same EU project also investigated the usefulness of GPS logger (and VMS) data, concluding that indicators of LPUE could be calculated if these data could be integrated with logbook landings information. Scotland's recently established Inshore Fisheries Groups (IFGs) may provide the impetus and the means to improve the knowledge base for the management of stocks locally. Data collection would however, need to be coordinated and maintained, to build up useful time series, and the need to improve the information collected on a national basis for both inshore and offshore fisheries is likely to remain.

Size-based indicators:
Size-based indicators and landings length frequency data have been investigated in this report. However, there were only a few unequivocal indications of variable recruitment apparent in the landings length frequencies. Discards in crab and lobster fisheries are sampled only on an irregular basis. More regular sampling to obtain information on catches of undersized animals could provide a better indication of inter-annual variation in recruitment. Further discard studies are also required to obtain estimates of discard survival and to help understand more fully the reasons for discarding.

Other factors:
The interpretation of trends in indicators derived from fishery dependent data would be helped by improved understanding of the economic and environmental factors which influence fishers' decision making with respect to fishing location and target species. A component of the Lot 1 EU project (Anon, 2010) involved conducting questionnaires and interviews to establish the main factors in fishers' decision making. As well as providing information on historical changes in fishing practices, the interview responses suggested that in recent years the Scottish brown crab fishery has been influenced more by the market than by management measures. Many fishers acknowledged that in 2008 the market price of brown crab was so low that the species was targeted to less extent than usual, which could explain the reduction in landings in some areas in that year. Additional information on factors affecting catchability such as bait type, creel density and soak time could also be collected in this way.

Population structure:
The population structure of crab and lobster stocks around Scotland (and the rest of the UK) is not well understood. The current assessment areas are empirical, based largely on past fishing patterns. Brown crab are known to undertake extensive seasonal migrations in some areas while in contrast velvet crabs and lobsters appear to make relatively limited movements. MSS recently conducted a tagging study of brown crab to the north of Scotland (Jones *et a*l., 2010). The results of this study suggest linkage between inshore and offshore crab stocks to the north and west of Scotland. Fishermen support the idea that crabs

migrate between (and across) the ‘windsock’ and inshore grounds around Orkney although there is only a limited fishery in the area in between. Large catches of female crab have also been reported on the shelf edge at depths greater than 200 m. Work being undertaken in both Shetland and Orkney, should provide further evidence regarding the structure of brown crab stocks to the north of Scotland. Ideally, such studies should be followed up by population genetics/morphology studies and consideration of larval dispersal. Based on the outcomes of the tagging work, the current brown crab assessment areas will be reviewed ahead of the next round of assessments.

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