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H Dobby, S Millar, L Blackadder, J Turriff and A McLay

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Helen Dobby, Sarah Millar, Lynda Blackadder and Anne McLay
Marine Scotland Science, Marine Laboratory
375 Victoria Road, Aberdeen, AB11 9DB

Executive Summary

This report presents the results of Scottish regional scallop stock assessments carried out by Marine Scotland Science (MSS) based on commercial catch-at-age and survey data up to and including 2010. Full analytical assessments are presented for the West of Kintyre, North West, North East and Shetland scallop stocks, with catch data presented for the Clyde, Irish Sea and Orkney. In addition, an exploratory analysis of the East Coast data is presented for the first time. The report also provides background information on Scottish fisheries for scallops, a description of the current management and regulatory framework and discusses potential management measures.

The Fisheries

- The Scottish commercial dredge fishery for the king scallop (*Pecten maximus)* began in the 1930s in the Clyde. It has since expanded around the coast of mainland Scotland and its islands to become the second most important shellfish fishery in Scotland. In 2010, total landings into Scotland were in excess of 9,000 tonnes with a value at first-sale of around £17.5 million. The landings in 2011 fell to just under 8,000 tonnes with a first-sale value of £16 million.
- The most important areas currently in terms of total landings are the Irish Sea, West of Kintyre, the North West, North East and East Coast. In 2010, over 80% of annual landings into Scotland were taken in these areas.
- Some areas, such as the Irish Sea, have shown systematic increases in reported landings, while in other areas the landings are characterised by occasional and rapid increases or declines. Some of these are associated with fishery closures due to the presence of amnesic or paralytic shellfish toxins, but others appear to be associated with strong year classes.

Stock Status

- The Time Series Analysis (TSA) stock assessments (performed for the first time) show that following periods of high recruitment during the mid 1990s, the main west coast stocks experienced poorer levels of recruitment in recent years which has resulted in declining biomass since then. The continued high catches in the West of Kintyre area are reflected in the recent increase in fishing mortality, although the estimates of fishing mortality (as estimated in the TSA) are relatively uncertain. In

contrast, the lower catches from the North West have resulted in a lower estimate of fishing mortality in this area.

- To the north east of Scotland (North East and Shetland assessment areas), recruitment is estimated to have been strong during the early 1990s, coinciding with increased catches, and more moderate in recent years. The fishing mortality in these areas increased during the late 1980s and in Shetland has increased again in recent years with the increases in catches.
- Stock trends based on the dredge survey data for the East Coast area suggest that spawning stock biomass (SSB) increased during the 2000s following a number of strong year classes. More recent recruitment appears to have been low and SSB is declining.
- There are insufficient data from the Clyde, the Irish Sea and Orkney assessment areas to perform analytical assessments or evaluate stock trends.

Management Considerations

- There are no agreed biomass or fishing mortality reference points for Scottish scallop stocks. MSS management advice is therefore currently provided on the basis of estimates of recent fishing mortality, recruitment and biomass in relation to historical values.
- For the West of Kintyre, where the stock is at a very reduced level, advice is for a reduction in fishing mortality (F). In the North West assessment area where fishing mortality has reduced but stock levels remain low, advice is for no increase in fishing mortality.
- In the North East and Shetland assessment areas, advice is for no increase in fishing mortality.
- Management measures to control fishing mortality could include: effort restrictions (through limits on kWdays or fleet size), spatial and temporal closures or limits on the quantity landed, either alone or in combination.
- Measures to increase the SSB should be considered for both the West of Kintyre and the North West assessment areas. An increase in minimum landing size was previously advised by MSS. This has the potential to increase the reproductive capacity of the stocks, providing there is no associated increase in fishing effort.
- Several administrations have interests and responsibilities for scallop fisheries in the Irish Sea. This highlights the need to bring together data from different sources to develop a more consistent, inclusive approach to the assessment and management of stocks in the area. The area has sustained particularly high landings over a long period of time with no apparent detriment to abundance. In such circumstances, advice is for no increase in effort.
- The lack of any clear stock recruitment relationship for scallops precludes the calculation of targets or reference points based on maximum sustainable yield. Other options based on per recruit analysis are discussed in the report and it is hoped to investigate these ahead of the next assessment scheduled for 2013.

Data and Quality of the Assessment

- In areas for which sufficient data were available, an age-structured Time Series Analysis (TSA) analytical assessment method was used. TSA provides more robust estimates of stock status than the method previously used as it makes use of multiple data sources (commercial catch-at-age and survey indices by age) and can cope with the omission of poor quality or missing data. In addition, the estimates of abundance and fishing mortality are calculated with confidence intervals.
- The estimates from TSA are smoothed through time reflecting the fact that fisheries and stocks are likely to show gradual year to year changes. As a result, the estimates are slow to respond, for example, when the data do suggest that there has been a sudden change in the fishery. This can potentially result in under or over estimation of recent fishing mortality.
- Historical trends estimated by the TSA approach show good agreement with MSS' previous stock assessments. The absolute levels of biomass, recruitment and fishing mortality estimated are not directly comparable with previous estimates as different procedures were used to derive these metrics.
- Commercial sampling levels have typically fallen in recent years due to limited staff and other higher work priorities. Although a single year with poor sampling is unlikely to significantly affect the conclusions of the assessment, continued poor sampling levels are likely to result in less precise and potentially biased results.
- The surveys are an essential component of the assessment in that they provide fishery independent indices of abundance. They show reasonably good coverage of the fished areas according to scallop dredge VMS data (over the recent period for which these data are available) with the exception of the West of Kintyre which could potentially result in biased abundance indices. Additional (or a redistribution of) survey stations in this area may provide a more representative index.
- TSA estimates that there has been an increase in survey catchability particularly in West of Kintyre scallops. It is not known whether this is related to changes in actual survey catchability (for example related to gear or design) or to a change in the distribution of stock and fishery in relation to the survey. The latter could potentially imply that the actual decrease in biomass is smaller than that estimated by the assessment which, therefore, provides a conservative estimate of biomass in this area.
- The population structure of Scottish scallop stocks is not well understood, and the assessment areas were defined to reflect the characteristics of the fisheries in the past. A recently funded MASTS (Marine Alliance for Science and Technology for Scotland) project aims to develop a spatial population model for scallops by combining ocean circulation models to simulate the dispersal patterns of larvae with models of the growth, survival and spawning of settled individuals. This should provide further information about the magnitude and scale of connectivity between scallop populations around Scotland which may have implications for the areas on which the assessments are based.

1. Introduction

1.1 Scottish Scallop Fisheries: An Overview

The commercial dredge fishery for the king scallop (*Pecten maximus*) in Scotland began in the 1930s as a seasonal (winter) fishery prosecuted by approximately 10 small inshore vessels in the Clyde. The fishery developed rapidly during the 1960s and 1970s, expanding northwards through the rest of the west coast of Scotland, around Shetland and the northeast Scottish coast, and is now a year round activity.

In 2010, total scallop landings into Scotland were in excess of 9,000 tonnes, which with a first-sale value of around £17.5 million[1] made the fishery the second most important shellfish fishery in Scotland. Over 95% of the landings came from dredge fisheries with the remainder taken by commercial divers.

The most important areas in terms of landings are the Irish Sea, West of Kintyre, the North West, North East and East Coast, with over 80% of annual Scottish landings typically taken in these areas.

The scallop dredge fleet consists of vessels ranging in size from under 10 m to around 30 m in length. The smaller vessels tend to work locally in inshore waters while the larger vessels are more nomadic and may move between fishing grounds around the coast of Scotland and the rest of the UK.

1.2 Management Framework and Regulations

Scottish scallop fisheries are not subject to EU or national TAC regulations. There are EU measures to restrict effort in addition to a variety of national regulations. Under the Western Waters effort regime (which applies to all UK waters except the North Sea), effort limits are applicable to all vessels over 15 m in length, including those fishing for scallops. The limits for UK vessels are 1,974,425 KW days for Sub-areas V and VI and 3,315,619 KW days for Sub-area VII (Council Regulation (EC) No. 1415/2004).

Minimum landing size (MLS) is also specified through EU legislation. In the Irish Sea north of 52°30'N, the MLS is 110 mm, while in all other areas a MLS of 100 mm applies (Council Regulation (EC) No. 850/98).

All vessels fishing commercially for scallops in Scotland are required to have a license and no new licenses are granted. The Prohibition of Fishing for Scallops (Scotland) Order 2003 introduced gear restrictions which vary according to where fishing takes place: a maximum of eight dredges per side is allowed in Scottish inshore waters (out to six nautical miles); a maximum of 10 per side in any other part of the UK territorial sea adjacent to Scotland (out

[1] In 2011, landings were just under 8,000 tonnes with a value of £16 million.

to 12 nautical miles); and 14 per side in any other part of the Scottish zone (out to 200 nautical miles). The Order also prohibits the use of "French" dredges (a design incorporating water deflecting plates and rigid fixed teeth) in Scottish inshore waters. In addition, a number of areas around Scotland are subject to seasonal (e.g. Luce Bay) or other temporal closures (weekend ban in the Clyde).

Shellfish fisheries (including the dredge fishery for scallops) around Shetland are managed under a Regulating Order (The Shetland Islands Regulated Fishery (Scotland) Order 1999) by the Shetland Shellfish Management Organisation (SSMO). Scallop vessels at Shetland are limited to a maximum of five dredges per side and to fishing within the hours of 0600 to 2100. As a condition of the licences issued by the SSMO, fishermen are required to provide detailed records of landings and fishing effort (Leslie *et al*., 2009).

The Scottish itinerant fleet of large dredge vessels regularly fish in the Irish Sea in the waters around the Isle of Man where their fishing activity is regulated by local (Isle of Man) legislation (Sea Fisheries (Scallop Fishing) Bye-Laws 1999 and 2010*)*. This includes various gear restrictions and curfews (dependent on zone) and a series of permanent and temporary closed areas.

2. Data Collection and Methods

2.1 Assessment Areas

For the purposes of Marine Scotland Science's (MSS) stock assessments, the scallop grounds around Scotland are divided into assessment areas (previously known as 'Management areas') which are defined on the basis of ICES[1] statistical rectangles (Figure 2.1.1 and Table 2.1.1). As in previous assessments, rectangle 40E4 is divided into two data components, one from the east side of the Mull of Kintyre and one from the west side. This allows for a clearer distinction between the West of Kintyre and Clyde scallop stocks.

2.2 Fishery Data

The stock assessments use a variety of fishery data which are described further below.

2.2.1 Landings data

The assessments make use of official landings data for both dredge and dive caught scallops. Scottish landings data (landings by UK vessels into Scotland) are collated by Marine Scotland Compliance from sales notes and EU logbooks, and held in the Fisheries Information Network (FIN) database and in MSS Fisheries Management Database (FMD). Landings data for scallops caught in Scottish waters but landed into other (non-Scottish) UK ports were provided by the Marine Scotland Marine Analytic Unit from the iFISH database.

[1] Technical and specialist terms (underlined) are defined in a glossary at the end of this report.

These data are only available for the period 2000 to 2010. For the purposes of the assessment, the average ratio of UK (England, Wales and Northern Ireland) landings to UK (Scotland) landings has been used to fill-in the missing historical data for the East Coast, North East and the West of Kintyre, whilst for the Irish Sea, historical data were taken from Howell *et al*. (2006).

Irish landings data were provided by the Marine Institute, Galway and recent landings into the Isle of Man were provided by Bangor University with permission from the Isle of Man Fisheries Directorate, Department of Environment, Food and Agriculture.

Total landings from each assessment area, by all fishing methods and by all nations, are used in the stock assessments.

2.2.2 Catch-at-age data

Scallop landings are sampled as part of an integrated MSS market sampling programme[1]. Sampling began in the early 1970s, however, it is only since 1982 that sufficient samples have been available to construct reliable catch-at-age data.

Most scallops in Scotland are sold privately, rather than by auction, and are sampled at the processing factories. For each trip sampled, one bag of scallops is selected at random and the lengths of all scallops are recorded to the 0.5 cm below. A sub-sample of the scallops are aged with all individuals age 10 and above recorded in a '10+' age category. Processors handle both dive and dredge caught scallops although dive caught samples are often obtained directly from the dive vessel at the time of landing.

Length at age data and sampled weights for dredge and dive caught scallops are combined and raised to total dredge landings on a quarterly basis. Quarterly data are summed to provide annual catch-at-age (composition) data for Scottish landings. These data are then raised to total annual landings (all nations) to provide input for the stock assessment. Raising factors are determined using a length-total weight relationship applied to the sampled data. Parameters are fixed across stocks and quarters (see Section 2.3).

2.2.3 Discards

Landings (totals and sampled age-composition) are assumed to be representative of catches and no discard sampling takes place. Results of survival experiments (Anon, 1995) suggest that mortality of discarded scallops is relatively low and the assumption of zero discard mortality is therefore unlikely to affect the reliability of the stock assessment.

[1] Samples from the Shetland area are collected and provided by staff from NAFC Marine Centre under the Memorandum of Understanding between NAFC Marine Centre and MSS.

2.3 Biological Data

2.3.1 Length-weight relationships

Two types of length-weight relationships are used in the stock assessment. A length-total weight (where weight is shell, gonad and muscle weight) relationship is used to raise sampled data to vessel landings. In addition, annual mean meat (muscle) weights at age are derived from the annual age-length composition data and area specific length-muscle weight relationships and these values are then used to convert the stock assessment outputs (which are in terms of numbers) into muscle weights. When insufficient data were available (for example due to missing age classes in particular years), an average of the weight at age over the previous three years was used as a fill-in.

The procedure above differs from the approach taken in previous stock assessments. Output was previously provided in terms of combined muscle and gonad weight which was derived using a quarterly mean weight-at-age fixed over all years (derived from mean quarterly lengths over 1991-1993 and a length-'muscle+gonad' weight relationship). Neither of the length-weight relationships have been updated in recent years. The stock specific parameter values are given in the relevant stock sections of the report.

2.3.2 Natural mortality

Natural mortality is not precisely known but in common with other fish and shellfish stocks of similar longevity (up to 20 years) it is assumed to be 0.15 yr^{-1} for all ages and areas (Cook *et al.*, 1990).

2.3.3 Maturity

Scallops first spawn in the autumn of their second year and 100% maturity is therefore assumed for age two onwards.

2.4 Research Vessel Surveys

Dredge surveys of the major scallop grounds around Scotland have been carried out by MSS since the mid 1990s (partial surveys of the west coast began in the late 1980s). There are three surveys a year which, collectively, cover the grounds of the west of Scotland, the North Sea (Scottish coast) and Shetland. The surveys have fixed stations. The station locations were determined with reference to sediment type, using British Geological Survey charts to locate sediments suitable for scallops and knowledge of the scallop fishing grounds contributed by skippers fishing at the time when the surveys first took place. The gear set-up consists of one array of standard commercial spring-loaded Newhaven type dredges (2.5' wide, 9 tooth bar, with 80 mm internal diameter belly rings, Type A), and another array of smaller configuration sampling dredges with 11 teeth and smaller diameter belly rings similar to commercial gear for queen scallops *Aequipecten opercularis* (2.5' wide, 11 tooth bar, with 60 mm internal diameter belly rings, Type B).

At each station the dredges are towed at a speed of about 2.5 knots for approximately 30 minutes and all scallops caught are aged and measured (length to the 0.5 cm below). Over the years, different survey dredge widths have been used. Catch rates are, therefore, standardised for both fishing time and dredge width and are presented as numbers caught per hour per metre dredge width (N hr^{-1} m^{-1}). Indices for each assessment area are calculated by aggregating total catch at age numbers from both dredge types over all hauls and dividing by total duration (and dredge width).

2.5 Assessment

Previous Scottish scallop stock assessments were carried out using a quarterly Virtual Population Analysis (VPA) (Howell *et al.*, 2006). A VPA does not provide an estimate of fishing mortality in the most recent year and additional data or assumptions were required to enable estimation of the stock status in the most recent year. Previously this was achieved by assuming that the temporal trend in fishing mortality was driven by changes in fishing effort ('effort tuning') or by making the assumption that the final year exploitation pattern was equal to the average (with tri-cubic weighting) over the available time series. Due to continuing effort data quality issues and potential inadequacies in the average exploitation pattern assumption, in the assessments presented here the scallop survey data were used as a tuning index within the stock assessment model. In previous assessments, the survey data were used only qualitatively. Results were presented spatially, in terms of total catch rates at each station, and were also used for comparison with the fishery data based stock assessment results (for example comparing recruitment estimates to survey catch rates of individuals < 100 mm).

A number of potential alternative assessment methods were considered, including the Lowestoft VPA suite of programs (Darby and Flatman, 1994). The Time Series Analysis (TSA) approach was chosen as it is was deemed to have a number of specific advantages over typical VPA type approaches including:

- Allows fishing mortality estimates to evolve over time in a constrained manner.
- Provides precision estimates of estimated parameters (numbers at age and fishing mortality at age).
- Can cope with the omission of catch or survey data if data are of poor quality or missing.
- Allows survey catchability to evolve over time.

TSA is not a conventional time series model in that it does not include autoregressive or moving average terms. It is a state space model with the state of the stock in a particular year described by a vector of stock numbers at age and fishing mortality at age (the 'state vector'). The 'state equations' define how this vector changes over time i.e. how the numbers at age in a particular year relate to the numbers at age and fishing mortality at age in the previous year. This vector is related to the data or observations (typically catch-at-age data and survey data) through ‘observation equations’. The Kalman filter is used to estimate the state variables. The method was derived by Gudmundsson (1994) and further developed by Fryer (2002) for use in the assessment of North Sea and West of Scotland demersal fish stocks (ICES, 2011).

The model is initialised and run through a series of R scripts although actual parameter estimation is carried out by a Fortran programme which is automatically called from within R.

3. Results and Discussion by Area

3.1 Regional and Temporal Trends

Since the mid 1990s, total Scottish scallop landings have fluctuated between eight and 10 thousand tonnes. The majority of these are dredge caught, dive caught scallops typically making up less than 5% of the total. Temporal trends in landings vary considerably between assessment areas and are shown in Table 3.1.1 (dredge) and Table 3.1.2 (dive) for 1982 to 2010 and for a longer period in Figure 3.1.1 (total landings by all vessels into all countries). In some areas, particularly to the west of Scotland, there have been substantial fisheries over a long period of time whilst in other areas such as the East Coast, North East and Orkney, fisheries developed relatively recently. The Irish Sea, Shetland and Orkney fisheries have shown a general increase in landings over the 45 year period illustrated, whilst the landings from some of the other assessment areas have shown declines. In particular, both the North East and North West areas have, in the past, had periods of very high landings (~ 3,500 t) but have shown a marked decline in recent years.

The spatial distribution of dredge landings in 2010 is shown in Figures 3.1.2 (landings into Scotland) and 3.1.3 (landings outside Scotland). The grounds of greatest importance to the dredge fishery in 2010 were the Irish Sea (around the Isle of Man), the northeast coast of Scotland, Shetland and the statistical rectangles around the Inner Hebrides. Note that a large proportion of landings from the Irish Sea were landed into ports elsewhere in the British Isles (not Scotland). There were also small landings from the East Coast and West of Kintyre into other UK ports (Table 3.1.3). Total landings into all countries are given in Table 3.1.4. In contrast to the dredge fisheries, the main dive fisheries in 2010, (Figure 3.1.4 and Table 3.1.2) were located in the coastal waters of the west of Scotland and at Orkney, where the method accounts for 40% of the landings.

3.2 West of Kintyre

3.2.1 Description of the Fishery

The West of Kintyre assessment area has a long history of exploitation with periods of high and low landings (Figure 3.1.1). The main fishing grounds are around the islands of Islay and Jura and the southern end of the Kintyre peninsula. The fishery operates year round. Landings have fluctuated between around 500 and 2,000 tonnes over the stock assessment period and in 2010 were above the long term average. The fishery is prosecuted regularly by a fleet of around 14 vessels which range from 9.9 m to approximately 20 m in length and typically land their catch into Tarbert, Tayinloan and Campbeltown. Up to six vessels from the Isle of Man may also fish this area at various times of the year.

3.2.2 Sampling Levels and Age Compositions

Sampling levels for the West of Kintyre are shown in Table 3.2.1. In 2010, the number of boats sampled varied between one and four per quarter, and the total number of scallops aged and measured was 2,124 (from 10 vessel landings sampled). Sampling levels fell substantially in 2010 when the number of sampled trips and individuals measured were both less than 50% of the 10 year average.

Catch-at-age Data

Catch-at-age data for the West of Kintyre, from 1982 to 2010 are shown in Table 3.2.2 and Figure 3.2.1. In the early part of the time series scallops eight years and older, and particularly 10+**,** were well represented in the catches, but have been less evident since the 1990s. In contrast**,** the number of scallops at ages four and five has increased considerably since this time. There was a notable lack of three years olds in the catch in 2001 and 2006, implying poor recruitment to the fishery. There has, however, been a steady increase in three years olds since then.

3.2.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) used for scallops in the West of Kintyre assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)
Muscle (annual)	0.00006634	2.668	MSS unpublished

The mean muscle weights are shown in Figure 3.2.2 and Table 3.2.3. The mean weight at age two has shown a gradual increase over the time period, while other ages up to seven show fluctuations but no specific trends. Mean weights at older ages show noticeable temporal trends which are similar across age classes, increasing through the early 2000s and decreasing more recently.

3.2.4 Exploratory Analyses

Catch Data

Catch curves by cohort for the commercial catch-at-age data are shown in Figure 3.2.3. These show partial recruitment to the fishery up to age five. Also evident are the low 1982-1986 year classes (recruitment in 1985-1989) and the particularly strong 1992-1994 cohorts. The gradient of the catch curves becomes increasingly steep during the mid 1990s which suggests an increase in fishing mortality.

Survey Data

Partial surveys of the west coast of Scotland began in 1988, with fuller coverage of both the West of Kintyre and North West assessment areas beginning in 1993. Details of the surveys are given in Table 3.2.4. The west coast survey has typically been carried out during early summer and, until 2000, it was very consistent in terms of timing, vessel and number of hauls. Since then, the timing has varied between August and April and a number of different vessels have been used in the survey. No comparative tows have been conducted between vessels, although catch rates are standardised by dredge width to account for differences in the number of dredges worked by each vessel. Survey data from 1993 (when full coverage began) to 2010 were used in the assessment of the West of Kintyre area.

The catch rates of scallops (all ages combined) at stations throughout the survey area between 2000 and 2010 are shown in Figure 3.2.4. Some stations, such as those off the east coast of Jura, show consistently high catch rates from year to year, whilst others show much more inter-annual variability. Table 3.2.5 shows the average catch rates by age class and year. Average catch rates of up to 15 scallops hr^{-1} m^{-1} occur for the most abundant ages. There has been a general decline in catch rates of the oldest ages in the most recent surveys. However, the index of three year olds in 2010 (10.35 scallops hr^{-1} m^{-1}) is the second highest on record.

Catch curve analyses (Figure 3.2.5) show the survey index by age on the log scale for each cohort. The steeply increasing left hand limb of these curves indicates that the youngest age classes (ages 2 and 3) have significantly lower survey catchability than older age classes. The earliest cohort curves are relatively smooth showing consistent tracking of year classes and selection. However, there appear to have been some changes in survey catchability, particularly evident in the 1998 to 2001 year classes, which do not show the typical declining pattern across ages four to seven. The increase in log catch numbers at age 10 (compared to age nine within a particular cohort) is due to the plus group effect i.e. this age class includes all individuals aged 10 and above. The magnitude of this effect is, however, highly variable from year to year and these data (the 10+ age group) are therefore excluded from the assessment.

3.2.5 Final Assessment

TSA

The exploratory catch curve analysis indicates highly variable catch rates of age two individuals in both the commercial catch and survey. In addition, the catch rates of the 10+ age group in the survey are very noisy. These data are, therefore, excluded from the final assessment. To summarise, the final TSA run uses the following data and settings:

Commercial catch-at-age data from 1982 – 2010, ages 3 – 10+
Dredge survey catch-at-age index from 1993 – 2010, ages 3 – 9
Average recruitment (i.e. no stock-recruit relationship assumed)
Age at full selection = 6
Survey timing = 0.45 (average survey timing as proportion of year, equivalent to mid June)

Outputs from the TSA assessment are shown in Figure 3.2.6 and estimated parameter values are given in Table 3.2.6.

Standardised prediction errors from the assessment model are shown in Figures 3.2.7 (landings) and 3.2.8 (survey). TSA is a state space time series model, and these prediction errors are an analogous (but not completely equivalent) diagnostic tool to residuals or fits used to assess other stock assessment models. The catch prediction errors are well distributed and do not suggest the model is predicting landings different to that of the observed data.

The survey prediction errors, however, show a distinct dome shaped pattern at the oldest ages, with this being especially apparent at ages eight and nine. It appears that the survey 'became better' at catching these older ages as time went on – reaching a peak for most ages around 2002, and then starting to decline again, showing a more evenly distributed pattern in the most recent years. This indicates changes in survey catchability that the model does not take account of. There is currently no explanation for this trend in catchability over a time when the survey gear and spatial distribution remained relatively stable.

There is no clear relationship between stock size (SSB) and recruitment to the fishery (at age three) for this stock, with large values for recruitment estimated at small stock sizes and small recruitments possible at both large and small stock sizes (Figure 3.2.9).

Retrospective Analysis

The retrospective plots shown in Figure 3.2.10 indicate that the assessment tends to overestimate SSB in the final year (i.e. that estimates are revised downwards with each additional year's data), and to underestimate mean fishing mortality, indicating there is some bias in the model, probably due to a mismatch between the signals in the catch and survey data. Recruitment is also revised as additional years are included in the stock assessment, although the estimates show neither systematic under or overestimation in the final year.

State of the Stock

The state of the stock is summarised in Figure 3.2.6. The final estimates for the stock in 2010 are:

F (average over ages 4-6) = 0.600 yr^{-1}
SSB (total over ages 3-10+) = 566 t (muscle weight)

There are no reference points for this stock.

Estimates (and standard errors) of age structured population abundance and fishing mortality are presented in Tables 3.2.7-3.2.10. The final estimates are smoothed across years which explains the differences between the estimates of fishing mortality at age in the first year given here and the parameter estimates in Table 3.2.6. Table 3.2.11 shows the stock summary. Mean F(4-6) showed a significant decline between 2003 and 2006, but since then is estimated to have more than doubled, although recent estimates are quite uncertain. Recruitment in 2010 is estimated as being lower than in the mid 1990s, but above the long-term average. The continued high catches combined with only moderate recruitment have, however, resulted in a declining SSB which is currently at the lowest level estimated over the 30 year time series.

Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2006 (Howell *et al*., 2006) and presented the results of an assessment conducted using commercial data up to and including 2003 in a quarterly VPA tuned to average fishing mortality. The assessment for West of Kintyre was updated in 2008 using data up to 2007 and this showed a substantial revision to the estimates of biomass and fishing mortality. A summary of stock status including biomass trends from the 2008 assessment can be found in the MSS Stock booklet (Scottish Government, 2010). The general trend (upwards) in estimated mean fishing mortality in this assessment is similar to that from the 2008 assessment, although the estimate is slightly lower. This may be due to the differences in the age range over which mean F is calculated in the two assessments. This assessment uses ages four to six but previous assessments used ages six to eight. The trends in SSB are also similar with an initial decline followed by an increase during the 1990s and then a further decline. The current assessment provides biomass estimates in terms of muscle weight only and absolute estimates are therefore not directly comparable with previous estimates which were of muscle plus gonad weight. Recruitment estimates from the two assessments (current and 2008) are of a comparable magnitude. Trends in the time series of recruitment at age three from the current stock assessment are similar to those previously estimated but with a time lag of one year due to the differing ages at which recruitment has been estimated (previously age two).

3.2.6 Quality of the Assessment

Landings Data

Fishers are required to provide information about quantities landed and fishing location by ICES rectangle on either EU logbooks or Shell 1 forms (under 10 m vessels). The implementation of 'the registration of buyers and sellers' legislation in the UK in 2006 requires details of the landed catch also to be recorded at the point of first sale and sales notes are cross checked against vessels landings declarations. This procedure is thought to have improved the accuracy of reported landings data in recent years.

Age Composition

The scallop market sampling levels in the West of Kintyre in 2010 were low due to lack of sampling opportunities and limited staff time. This issue is currently under review with the aim to increase sampling levels throughout the year in the West of Kintyre and other areas. Provided that previous sampling levels have been adequate, the reduction in a single year (2010) should not significantly affect the assessment of stock status.

Weights at Age

Mean muscle weights-at-age used in this assessment were derived from a length-weight relationship (unpublished MSS) and the size at age composition data collected through the market sampling programme. This allows for inter-annual variation in weights-at-age (due to changes in size-at-age) to be accounted for in the estimate of SSB. In previous assessments, fixed values for weight-at-age were used.

Survey Data

The survey provides good coverage of the fishing grounds off the east coast of Islay and Jura and to the west of the Kintyre peninsula. However, there are relatively few stations in statistical rectangle 41E4 which covers the north of Jura and the area to the southeast of Mull, where significant landings were reported in 2010.

The survey utilises a standard commercial dredge with large belly rings and a smaller laboratory dredge with small belly rings. Younger age classes (two and three year olds) have lower survey catchability because they are smaller and are able to pass through the belly rings of the dredge. However, occasional large catches are possible because other scallops and debris block their escape through the dredge. Variability in survey vessel and timing of the survey may also result in noisy data with apparently changing catchabilities, but not a systematic trend in particular age classes.

Model Formulation

TSA is useful in that it allows both fishing mortality and survey catchability to evolve over time in a constrained manner. However, the current model formulation does not allow for survey catchability trends to differ between age classes resulting in some systematic trends in the standardised survey prediction errors in the final run.

3.2.7 Management Considerations

SSB has declined markedly in the last ten years and recent estimates of fishing mortality for the West of Kintyre assessment area are high. Under these circumstances advice is for a reduction in fishing mortality. Management measures to control fishing mortality could include: effort restrictions (through limits on kWdays or fleet size), spatial and temporal closures or limits on the quantity landed, either alone or in combination.

Measures to increase SSB should be considered. An increase in the minimum landing size has previously been proposed by MS as a possible management measure for Scottish scallop fisheries. The survival of discarded scallops is high and therefore most undersized scallops returned to the sea have the potential to grow. This measure therefore has the potential to increase the reproductive capacity of the stock, provided that there is no associated increase in fishing effort.

3.3 North West

3.3.1 Description of the Fishery

The North West assessment area covers much of the west coast of Scotland and the waters around the Hebrides. There is a long history of scallop fishing in this area (Figure 3.1.1). The main fishing grounds are around the Inner Hebrides and South Uist. The fishery operates year round. In 2010, landings were 1,365 t, 30% of the peak of 4,500 t taken from the area in 2002. The fishery is prosecuted by a fleet of around 10 vessels which range in size from 9.9 m to approximately 18 m and land their catch into Mallaig, Kallin, Uig, Kyle, Portree, Lochinver and Ullapool. There are approximately 12 nomadic vessels which fish in this area at various times of the year, and a small but significant dive fishery which consists of approximately six dive vessels. The dive fishery operates largely in the sheltered inshore waters around Ullapool, Uig, Kyle, Uist and Barra and in 2010 accounted for just over 15% of total scallop landings in the North West area.

3.3.2 Sampling Levels and Age Compositions

Sampling levels for the North West area are shown in Table 3.3.1. In 2010, 5142 individual scallops were measured from 31 sampled vessels. This is an improvement on recent years and comparable to sampling levels from the start of the time series, although seasonal coverage varied with only one sample obtained during quarter one, compared to 15 in quarter two.

Catch-at-age Data

Catch-at-age data for the North West from 1982 to 2010 are shown in Table 3.3.2 and Figure 3.3.1. In the early part of the time series, catches were dominated by individuals in the 10+ age category, whereas more recently, the catches consist largely of four, five and six year old individuals. Since 2006, there has been a noticeable lack of three year olds in the catch suggesting poor recruitment.

3.3.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) used for scallops in the North West assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)
Muscle (annual)	0.00008563	2.668	MSS unpublished

The mean muscle weights are shown in Figure 3.3.2 and Table 3.3.3. The mean weights of individuals aged five to ten shows a gradual increase from the late 1980s to mid 1990s with similar inter-annual variations across age classes. Mean weights for those age categories which are less important in the catch show greater fluctuations.

3.3.4 Exploratory Analysis

Catch Data

Catch curves by cohort for the commercial catch-at-age data are shown in Figure 3.3.3. These show that age classes younger than age five are typically only partially recruited to the fishery. Clearly apparent are the very low 1982-1986 year classes, recruiting to the fishery at age three in 1985-1989, and the strong 1996-1999 cohorts, recruiting at age three in 1999-2002. These large year classes appear to have been subject to much higher fishing mortality (as evidenced by the steep slope) than those cohorts recruiting in the early 1980s. The unexpectedly low catches of the 1990 cohort at age nine, the 1991 cohort at age eight, etc. occurs across all age classes. These are due to the sudden decline in total landings in 1999, a result of the amnesic/paralytic shellfish poisoning (ASP/PSP) fishery closures in the assessment area. The increase in log catch numbers at age 10 (compared to age nine within a particular cohort) is an effect of the plus group i.e. this age class includes all individuals aged 10 and above.

Survey Data

Details of west coast scallop surveys which cover the North West assessment area are given in Table 3.2.4. This shows the relative consistency in terms of vessel, timing and number of hauls prior to 2000 with greater variability in all aspects since then. To account for vessel changes (working different numbers of dredges), the catch rates are standardised by total dredge width. Survey data from 1993 onwards (the first year of full spatial coverage) are included in the assessment of the North West area.

The catch rates of scallops (all ages combined) at stations throughout the survey area between 2000 and 2010 are shown in Figure 3.3.4. Total catch rates across much of the region have shown a marked decline since 2006. Table 3.3.4 shows the average catch rates by age class and year. In the most recent surveys, average catch rates have fallen across a range of age classes, most notably ages three to six. The plus group in recent years will contain the survivors of the very strong year-classes recruiting in the late 1990s and early 2000s (apparent as high catch rates at age three and four earlier in the time series) and catch rates of this age class remain relatively high.

Catch curve analyses are shown in Figure 3.3.5 and show the survey index by age (ages two to 10+) on the log scale for each cohort. Ages two and three are seen to have consistently lower survey catchability than individuals from the older age classes. The cohort curves are relatively smooth showing consistent tracking of year classes and selection. The increase in log catch numbers at age 10 (compared to age 9 within a particular cohort) is due to the plus group effect i.e. this age class includes all individuals aged 10 and above.

3.3.5 Final Assessment

TSA

The exploratory catch curve analysis shows low and highly variable catch rates of age two individuals in both the commercial catch and survey. In addition, the catch rates of the 10+ age group in the survey are very noisy. These data are therefore excluded from the final assessment. To summarise, the final TSA run uses the following data and settings:

Commercial catch-at-age data from 1982 – 2010, ages 3 – 10+
Dredge survey catch-at-age index from 1993 – 2010, ages 3 – 9
Average recruitment (i.e. no stock-recruit relationship assumed)
Age at full selection = 6
Survey timing = 0.45 (average survey timing as proportion of year, equivalent to mid June)

Outputs from the TSA assessment are shown in Figure 3.3.6 and estimated parameters given in Table 3.3.5.

Standardised prediction errors from the assessment model are shown in Figures 3.3.7 (landings) and 3.3.8 (survey). The landings prediction errors are greatest and show some similar trends across age classes during the middle of the time series when the level of the landings fluctuates between high and low over consecutive years. In 1999, coinciding with the very low total landings due the ASP/PSP fishery closures, all age classes show a negative landings prediction error indicating that the observed value is lower than the value predicted by the model. In subsequent years the residuals are typically positive. Fishing mortalities evolve relatively slowly in TSA which can result in systematic prediction errors when the fishery (total catches) fluctuates rapidly. Most of the prediction errors are generally of low magnitude (between plus and minus two) and not sufficient to invalidate the fit of the model to the data.

The standardised survey prediction errors suggest increasing survey catchability through the time series for ages six to eight, but decreasing catchability for ages three and four. As in the West of Kintyre, these apparent changes in survey catchability cannot be associated with any particular changes to the survey. The age nine class show a number of outlying errors with greater magnitude – one due to the abnormally high catches of age nine individuals in 2005 (significantly higher than age eight in 2004) and the other a much lower than expected catch of age nine in 2010. Prediction errors for all other age classes are generally of low magnitude.

The relationship between estimated spawning stock biomass (SSB) and recruitment at age three is particularly poor, with high and low recruitment occurring at both small and large stock size (Figure 3.3.9).

Retrospective Analysis

The retrospective plots are shown in Figure 3.3.10. These show that the assessment tends to overestimate SSB in the final year. The addition of data from 2009 and 2010 resulted in a significant downwards revision to the SSB estimates from around 2000 onwards, coupled with downward revision to recruitment and an upwards revision to the estimates of mean fishing mortality. Further exploration of the estimated parameters reveals that the estimated survey catchabilities show a substantial upwards revision (although the trend is still downwards) with the addition of the 2009 survey data. This results in the recruitment being revised downwards and the mean F being revised upwards. Retrospective patterns since 2009 are less apparent.

State of the Stock

The state of the stock is summarised in Figure 3.3.6. The final estimates for the stock in 2010 are:

F (average over ages 4-6) = 0.111 yr^{-1}
SSB (total over ages 3-10+) = 2,689 t (muscle weight)

There are no reference points for this stock.

Estimates (and standard errors) of age structured population abundance and fishing mortality are presented in Tables 3.3.6-3.3.9. The final estimates are smoothed across years which results in differences between the estimates of fishing mortality at age in the first year given here and the parameter estimates in Table 3.3.5.

Table 3.3.10 shows the stock summary. Following a period of high recruitment in the late 1990s and early 2000s, recruitment has declined and has been below the long term average since 2006. As a result SSB has also declined from the relatively very high levels of 10 years ago. Catches have been low in recent years and this is reflected by the low fishing mortality.

Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2006 (Howell *et al*., 2006) and presented the results of an assessment conducted using commercial data up to and including 2003 in a quarterly VPA tuned to average fishing mortality. The assessment for the North West was updated in 2008 using data up to 2007 and a summary of stock status including biomass trends can be found in the MSS Stock booklet (Scottish Government, 2010). The historical trends in SSB and recruitment as estimated in the current assessment show some agreement with those estimated previously. Biomass initially declines through the 1980s, reaching the lowest estimated values around 1990 and then increases to a maximum in 2000. (Note the current assessment provides biomass estimates in terms of muscle weight only which are not directly comparable, in terms of absolute value, to previous estimates which were of muscle plus gonad weight). The general trend in estimated mean F from the current assessment is similar to that estimated by Howell *et al.* (2006) although the level is slightly lower. This may be due to differences in the age range over which mean F is calculated in the two assessments. This assessment uses ages four to six, whereas previously it was for ages six to eight.

3.3.6 Quality of the Assessment

Landings Data

Fishers are required to provide information about quantities landed and fishing location by ICES rectangle on either EU logbooks or Shell 1 forms (under 10 m vessels). The implementation of ‘the registration of buyers and sellers’ legislation in the UK in 2006 requires details of the landed catch also to be recorded at the point of first sale and sales notes are cross checked against vessels landings declarations. This procedure is thought to have improved the accuracy of reported landings data in recent years.

Age Composition

The scallop market sampling levels (number of trips and number of scallops sampled) for the North West in 2010 were at the highest level since 2003. During the mid to late 2000s sampling levels were lower which may explain the highly variable catch curves during these years. The lack of consistency in sampling throughout the year (i.e. some quarters not sampled) may also cause bias and/or noise in the annual catch-at-age data.

Weights at Age

Mean muscle weights-at-age are now derived from a length-weight relationship (unpublished MSS) and the size at age composition data collected through the market sampling programme. This allows for inter-annual variation in weights-at-age (due to changes in size-at-age) to be accounted for in the estimate of SSB. Previously fixed values for weight-at-age were used.

Survey Data

Survey stations are located in most of the major fishing areas of the North West assessment area. The exceptions are the area to the western tip of Skye and the inshore waters of the east coast of Lewis, Harris and North Uist where there has been some fishing activity (inferred from VMS data) in recent years.

The survey utilises a standard commercial dredge with large belly rings and a smaller laboratory dredge with small belly rings. Younger age classes (two and three year olds) have lower survey catchability because they are smaller and are able to pass through the belly rings of the dredge. However, occasional large catches are possible because other scallops and debris block their escape through the dredge. Variability in survey vessel and timing may also result in noisy data with apparently changing catchabilities, but not a systematic trend in particular age classes.

Model Formulation

TSA is useful in that it allows both fishing mortality and survey catchability to evolve over time in a constrained manner. However, the current model formulation does not allow for survey catchability trends to differ between age classes resulting in some systematic trends in the standardised survey prediction errors in the final run.

3.3.7 Management Considerations

SSB, recruitment and catch have all declined markedly in the North West assessment area over the last ten years. Measures to increase spawning stock biomass should be considered. However given the apparent temporal autocorrelation in recruitment (i.e. successive recruitments are correlated), it is unlikely that SSB will increase quickly even at the current relatively low fishing mortality. An increase in the minimum landing size has been proposed as a possible management measure for Scottish scallop fisheries. The survival of discarded scallops is high and therefore most undersized scallops returned to the sea have the potential to grow. This measure therefore has the potential to increase the reproductive capacity of the stock, provided that there is no associated increase in fishing effort.

Management measures to control fishing mortality should be considered and could include: effort restrictions (through limits on kWdays or fleet size), spatial and temporal closures or limits on the quantity landed, either alone or in combination.

3.4 Clyde

3.4.1 Description of the Fishery

The Scottish commercial scallop fishery began in the Clyde in the 1960s. Landings have fluctuated markedly over the ensuing period, declining to under 20 tonnes in 1990 and increasing since then to over 500 tonnes in 2010 (Figure 3.1.1). The fishery is prosecuted by two Campbeltown vessels and vessels from the Isle of Man fleet (up to six vessels) which fish in the Clyde at various times of the year. The scallop vessels vary in size from 9.9 m to approximately 20 m and regularly land into Campbeltown or occasionally into Ayr and Troon.

3.4.2 Sampling Levels and Age Compositions

In 2010 over 2,500 scallops were measured in the Clyde assessment area from 11 fishing trips during quarters one to three. In previous years, sampling of Clyde landings has been rather limited in terms of seasonal coverage and number of trips sampled (Table 3.4.1).

Catch-at-age Data

Raised catch-at-age data for the Clyde area are available in FMD from 1982 to 2010. However, given the low historical sampling levels, these data are not deemed of sufficient quality for further analysis and are not presented here.

3.4.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) available for scallops in the Clyde assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al*. (1990)
Muscle (annual)	0.00006634	2.668	MSS unpublished

3.4.4 Assessments

Due to the limited port sampling, the age composition data are insufficient for carrying out a reliable TSA assessment. No survey data are available for the Clyde assessment area. In the absence of an assessment, advice on management or management measures specific to the Clyde assessment area have not been considered here.

3.5 Irish Sea

3.5.1 Description of the Fishery

The Irish Sea scallop assessment area covers the waters to the south west of Scotland from latitude 55˚ N to 53˚ N. The fishery began in the 1970s and landings (into Scotland) have steadily increased to a peak of 1,461 t in 2010, establishing the Irish Sea as one of the main fishing grounds in terms of landings into Scotland. At various times of the year approximately 20 large (15-20 m in length) nomadic Scottish vessels fish the Irish Sea particularly in Luce Bay, scallop grounds off Burrow Head and around the Isle of Man. These vessels normally land at Kirkudbright or the Isle of Whithorn, but depending on fishing locations, they may also land to ports on Anglesey and up the coast of England or into Peel (Isle of Man). The majority of landings from the Irish Sea assessment area are landed into ports outside Scotland with a large proportion taken by non-Scottish vessels.

A by-law, introduced by the Isle of Man Government in 2010, resulted in a number of larger vessels in the Scottish scallop fleet being excluded from fishing grounds in Isle of Man waters. Concerns about displaced fishing effort, particularly into Luce Bay (a designated SAC) in southwest Scotland resulted in a four month extension to the seasonal closure of this area in 2010-11, under The Scallops (Luce Bay) (Prohibition of Fishing) Order 2010.

3.5.2 Sampling Levels and Age Compositions

The landings from Kirkcudbright (the main Irish Sea landing port) have been sampled irregularly with a total of only 3,500 scallops measured between 2008 and 2010 (Table 3.5.1). Over half of the landings from the Irish Sea assessment area are landed into other UK ports (out-with Scotland), which makes obtaining representative fishery data from this area particularly difficult.

Catch-at-age Data

Catch-at-age data raised to Scottish landings for the Irish Sea area are available in FMD for the mid 1980s onwards. However, given that these are based on a small number of samples taken only at Scottish ports, these data are not deemed of sufficient quality for further analysis and are not presented here.

3.5.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) available for scallops in the Irish Sea assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)
Muscle (annual)	0.00006634	2.668	MSS unpublished

3.5.4 Assessments

The available age composition data are insufficient for an analytical assessment, and no surveys have been undertaken in this area by MSS. Since 2007, however, Bangor University has undertaken a programme of research and monitoring of species of fisheries and conservation importance (including scallops) in the waters surrounding the Isle of Man. Their most recent assessment of stock status is based on a time series of abundance estimates from biannual dredge surveys conducted across the scallop fishing grounds around the Isle of Man (Murray *et al.,* 2009). The index of total abundance shows an increase in recent years although this appears largely due to major increases in abundance on a limited number of scallop grounds. Applying a precautionary approach (PA), recent advice from Bangor University (Murray *et al.*, 2009) has been for no increase in catches, with the acknowledgement that landings figures are likely to be incomplete due to the unavailability of landings data from the other UK (non Scotland) administrations.

3.5.5 Management Considerations

Several administrations have interests and responsibilities for scallop fisheries in the Irish Sea. This highlights the need to bring together data from different sources to develop a more consistent, multilateral approach to the management of stocks in the area. MSS scientists have been involved in a proposal to set up an ICES Working Group on scallops which should facilitate the scientific collaboration required to produce robust stock assessments for this area.

The area has sustained particularly high landings over a long period of time with no apparent detriment to abundance. In such circumstances, advice is for no increase in effort.

East Scotland (East of 4ºW)

3.6 North East

3.6.1 Description of the Fishery

The North East scallop fishery developed in the 1980s and landings have fluctuated throughout the time series with a peak of 3,491 t in 1996 but falling to 1,267 t in 2010

(Figure 3.1.1). Large nomadic vessels (over 15 m) fish the scallop grounds in the inner and outer Moray Firth with approximately six vessels also fishing grounds to the east coast of the northern Orkney Isles. These vessels land regularly into Wick, Buckie and Fraserburgh.

3.6.2 Sampling Levels and Age Compositions

Sampling levels for the North East area are shown in Table 3.6.1. Previously, landings from all four quarters were sampled relatively consistently, however, in recent years some quarters are un-sampled. This may reflect seasonality in fishing patterns (a lack of trips to sample), but the total number of samples obtained has also fallen (only six trips were sampled in 2010).

Catch-at-age Data

Catch-at-age data for the North East are available from 1984 to 2010. The data are shown in Table 3.6.2 and Figure 3.6.1. In the early part of the time series, catches were dominated by individuals in the 10+ age category, whereas more recently, the catches consist largely of age four to seven year olds.

3.6.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) available for scallops in the North East assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)
Muscle (annual)	0.00006386	2.668	MSS unpublished

The mean muscle weights are shown in Figure 3.6.2 and Table 3.6.3. The historical mean weights at age show variability, but no systematic trend until the mid 2000s when mean weights of older individuals increased up to 2008 and then declined. Inter-annual fluctuations in mean weight at age are similar across age classes.

3.6.4 Exploratory Analyses

Catch Data

Catch curves by cohort for the commercial catch-at-age data are shown in Figure 3.6.3. In general, these data appear quite variable which may be due to the rapid fluctuations which have occurred in the fishery in this area (due to effort displacement from areas closed to scallop fishing due to ASP/PSP toxins), but which could also be due to the relatively low sampling levels during the early and latter part of the time series. The catch curves show partial recruitment to the fishery up to age five. Those from the early cohorts show an unusual increasing pattern which is due to the rapidly increasing fishery during the first

10 years (approximately) of the time series. There are above average catch curves for the 1988 to 1991 cohorts (recruitment in 1991 to 1994) which decline relatively steeply, suggesting strong year classes with higher than average mortality.

Survey Data

A partial North Sea scallop survey was conducted in 1993, with full coverage of the North East assessment area beginning in 1994. Details of the surveys are given in Table 3.6.4 and the spatial distribution of stations is shown in Figure 3.6.4 for surveys from 2000 to 2010. Since 2001, the survey has been relatively consistent in terms of timing (June/July) and vessel. However, prior to this the survey was conducted towards the end of the year, between September and December, and in one instance in the following calendar year, the 1998 survey being conducted in January/February 1999. As for the west coast survey, no comparative tows have been conducted to compare catch rates between vessels and standardisation involves dividing the catch rate by dredge width to account for differences in the number of dredges worked.

The catch rates of scallops (all ages combined) at stations across the North East area between 2000 and 2010 are shown in Figure 3.6.4. The lowest catch rates typically occur at the stations in the offshore areas of the central Moray Firth while higher catch rates are generally found in the inner Moray Firth. Table 3.6.5 shows the average catch rates by age class and year. The highest catch rates (> 10 $hr^{-1}m^{-1}$) are observed at the start of the survey time series and are of the strong 1989 and 1990 year classes, first appearing at age five and four (respectively) in the 1994 survey (and then one year older in subsequent surveys). Since then catch rates have in general been less than five individuals $hr^{-1}m^{-1}$.

Catch curve analyses are shown in Figure 3.6.5 and show the survey index by age on the log scale for each cohort. The steeply increasing left hand limb of these curves indicates that the youngest age classes (ages two and three) have significantly lower survey catchability than older age classes. The cohort curves of 1988 to 1991 are relatively smooth showing good tracking of year classes (which are particularly strong in 1989 and 1990) and consistent selection. The year class curves of the weak 1993 and 1994 cohorts are unusual in that they are relatively flat and show little decline in log numbers at older ages suggesting increasing catchability of the older ages for a period of time.

3.6.5 Final Assessment

TSA

The exploratory catch curve analysis shows low and highly variable catch rates of age two individuals in both the commercial catch and survey. In addition, the catch rates of the 10+ age group in the survey are considered too noisy to be included in the assessment. To summarise, the final TSA run for the North East area uses the following data and settings:

Commercial catch-at-age data from 1984 – 2010, ages 3 – 10+
Dredge survey catch-at-age index from 1994 – 2010, ages 3 – 9
Average recruitment (i.e. no stock-recruit relationship assumed)
Age at full selection = 6
Survey timing = 0.58 (average survey timing as proportion of year)

Outputs from the TSA assessment are shown in Figure 3.6.6 and estimated parameter values are given in Table 3.6.6.

Standardised prediction errors from the assessment model are shown in Figures 3.6.7 (landings) and 3.6.8 (survey). The majority of the catch prediction errors are well distributed about zero. There are, however, a number of significant outliers which may be the result of noisy catch composition data due to low sampling levels, particularly during the early part of the time series.

The survey prediction errors are well distributed and do not suggest that the model is predicting survey indices different to the observed data. In contrast to the west coast, there is no evidence to indicate age-related differences in catchability trends.

There is no clear relationship between stock size (SSB) and recruitment at age three for this stock, although examination of the data suggests that high recruitment is associated with low stock sizes (Figure 3.6.9).

Retrospective Analysis

The results of the retrospective analysis are shown in Figure 3.6.10. There is some tendency for the assessment to overestimate SSB and underestimate fishing mortality in the final year although this appears to be less of a problem between 2009 and 2010 than 2008 and 2009. There are no systematic revisions to recruitment estimates in the final year or for any historical estimates of the stock status metrics (F and SSB).

State of the Stock

The state of the stock is summarised in Figure 3.6.6. The final estimates for the stock in 2010 are:

F(average over ages 4-6) = 0.176 yr^{-1}
SSB (total over ages 3-10+) = 1,214 t (muscle weight)

There are no reference points for this stock.

Estimates (and standard errors) of age-structured population abundance and fishing mortality are presented in Tables 3.6.7-3.6.10. Table 3.6.11 shows the stock summary. Fishing mortality on this stock increased rapidly during the late 1980s and early 1990s. Over the last five years it has been more stable, fluctuating at around 0.2 yr^{-1} (above the long term average), but with significant uncertainty surrounding the estimates throughout the time period. SSB has declined slightly in recent years after a period of relatively stable/increasing SSB since the mid 1990s. Recruitment has also declined in recent years, although it was slightly higher in 2010 than 2009.

Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2006 (Howell *et al*., 2006) and presented the results of an assessment conducted using commercial data up to and including 2003 in a quarterly VPA tuned to average fishing mortality). The assessment for the North East was updated in 2008 using data up to 2007 and a summary of stock status including biomass trends can be found in the MSS Stock booklet (Scottish Government, 2010). Trends in the time series of recruitment at age three from the current stock assessment are similar to those previously estimated but with a time lag of one year due to the differing ages at which recruitment has been estimated (previously age two). Trends in SSB and fishing mortality as estimated in the current assessment are broadly similar to those previously estimated. Levels of mean F and SSB are not comparable to earlier estimates as mean F was previously calculated over ages six to eight (in the current assessment it is estimated for ages four to six) and SSB was previously presented as muscle plus gonad, whereas in this assessment it is muscle only.

3.6.6 Quality of the Assessment

Landings Data

Fishers are required to provide information about quantities landed and fishing location by ICES rectangle on either EU logbooks or Shell 1 forms (under 10 m vessels). The implementation of ‘the registration of buyers and sellers’ legislation in the UK in 2006 requires details of the landed catch also to be recorded at the point of first sale and sales notes are cross checked against vessels landings declarations. This procedure is thought to have improved the accuracy of reported landings data in recent years.

Age Composition

The scallop market sampling levels for the North East were poor, in terms of both total number of trips and seasonal coverage of the fishery, at the start of the time series and again more recently. Catch-at-age composition data for these periods are therefore likely to be less reliable, resulting in greater uncertainty in estimated stock status.

Weights at Age

Mean muscle weights-at-age are now derived from a length-weight relationship (unpublished MSS) and the size at age composition data collected through the market sampling programme. This allows for inter-annual variation in weights-at-age (due to changes in size-at-age) to be accounted for in the estimate of SSB. Previously, fixed values for weight-at-age were used.

Survey Data

Survey stations are located in most of the major fishing areas (inferred from VMS data) of the North East assessment area. However, there appears to be significant spatial variability in the intensity of sampling (as a result of the original fixed station survey design), with some grounds such as those off the north Moray coast and to the east of Orkney much more intensely sampled than the large central offshore fishing grounds.

The survey utilises a standard commercial dredge with large belly rings and a smaller laboratory dredge with small belly rings. Younger age classes (two and three year olds) have lower survey catchability because they are smaller in length and width and are able to pass through the belly rings of the dredge. However, occasional large catches are possible because other scallops and debris block their escape through the dredge which may result in variable catchability.

Model Formulation

TSA is useful in that it allows both fishing mortality and survey catchability to evolve over time in a constrained manner. Precision estimates are provided for the parameters of interest which is extremely useful in this case as it highlights the extent of the uncertainty surrounding the estimates of mean F potentially associated with low sampling levels.

3.6.7 Management Considerations

Recruitment and SSB have been relatively stable in recent years, although below the long term average for this stock. Fishing mortality has been above the long term average. In such circumstances advice is for no increase in fishing mortality. Management measures to control fishing mortality could include: effort restrictions (through limits on kWdays or fleet size), spatial and temporal closures or limits on the quantity landed, either alone or in combination.

3.7 Shetland

3.7.1 Description of the Fishery

The Shetland scallop fishery developed in the late 1960s and landings have steadily increased to a high of 1,071t in 2010. Large scallops vessels (>15 m) generally target the grounds around the Islands of Whalsay and Fetlar in the north east of Shetland and to a lesser extent grounds in the North of Yell Sound. Around 30 dredge vessels are licensed under the Regulating Order (RO) by the SSMO to fish at Shetland.

3.7.2 Sampling Levels and Age Compositions

Sampling levels for the Shetland area are shown in Table 3.7.1. In 2010, 6,512 individual scallops were measured from 65 sampled trips. The landings from the Shetland area have been consistently well sampled since the late 1980s.

Catch-at-age Data

Catch-at-age data for Shetland are shown in Table 3.7.2 and Figure 3.7.1 for 1985 onwards. The catches are dominated by individuals from age classes four to seven, although the 10+ category also represents a significant component of the catch. Individuals aged three and under only appear in the catch with the occurrence of a strong year class, for example age three in 2005 and 2006, and age two in 1992.

3.7.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) available for scallops in the Shetland assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)
Muscle (annual)	0.00007599	2.668	MSS unpublished

The mean muscle weights are shown in Figure 3.7.2 and Table 3.7.3. There is a gradually increasing trend in mean weight at age over all ages through the 2000s, which appears to have levelled off more recently. Inter-annual fluctuations in mean weight at age are similar across age classes.

3.7.4 Exploratory Analysis

Catch Data

Catch curves by cohort for the commercial catch-at-age data are shown in Figure 3.7.3. On the whole the catch curves are relatively smooth, in comparison to those from other areas, which may be due to the consistently good sampling levels in this area. The strong 1989 and 1990 year classes (recruitment in 1992 and 1993) are clearly apparent as above average catch curves, whilst the 1994 and 1995 catch curves are below average, indicating low recruitment in 1997 and 1998.

Survey Data

Details of the surveys which have been carried out at Shetland are given in Table 3.7.4. Typically, the survey has been carried out in late winter (February/March), although there have been a number of exceptions to this: the 2002 survey was carried out three months earlier than usual at the end of 2001 and the first two surveys (1995 and 1996) were carried out in May. The majority of the surveys were carried out on the FRV *Clupea* (1998-2008). The catch rates have been standardised by dredge width to account for changes in vessel i.e. different vessels working different numbers of dredges. Survey data from 1995 onwards are included in the assessment of the Shetland area.

The number of valid survey stations is usually between 80 and 90. However, bad weather has occasionally disrupted the survey resulting in reduced numbers of stations in 2000, 2004, 2008 and 2009. The stations which were missed on these surveys are generally those to the south west of Shetland and in other exposed locations. It is not possible to determine whether lack of data from these areas has significantly biased the survey catch-at-age indices in these years.

The catch rates of scallops (all ages combined) at stations throughout the survey area between 2000 and 2010 are shown in Figure 3.7.4. High catch rates are relatively consistently recorded at the stations in Yell Sound on the north coast. Catch rates along the south east coast of mainland Shetland show quite significant inter-annual variability. Table 3.7.5 shows the average catch rates by age class and year. The highest catch rate (~ 9 individuals $hr^{-1}m^{-1}$) is observed at age five in 1995 and is the result of the strong 1990 year class (also observed in the commercial catch curves).

Catch curve analyses are shown in Figure 3.7.5 and show the survey index by age on the log scale for each cohort. The steeply increasing left hand limb of these curves indicates that the youngest age classes (ages two and three) have significantly lower survey catchability than older age classes. The early cohort curves in particular, are relatively smooth, showing good tracking of year classes and consistent selection. Recent year classes (2004-2006) appear to be of below average abundance.

3.7.5 Final Assessment

TSA

Catch rates of age two individuals are low and highly variable in both the commercial catch and survey (as seen from the exploratory analysis). In addition, catch rates for the 10+ age class are also quite noisy. These age classes are therefore excluded from the final assessment. To summarise, the final TSA run uses the following data and settings:

> Commercial catch-at-age data from 1986-2010, ages 3-9
> Dredge survey catch-at-age index from 1995-2010 (1997 missing year), ages 3-9
> Average recruitment (i.e. no stock-recruit relationship assumed)
> Age at full selection = 7

Outputs from the TSA assessment are shown in Figure 3.7.6 and estimated parameter values are given in Table 3.7.6.

Standardised prediction errors from the assessment model are shown in Figures 3.7.7 (landings) and 3.7.8 (survey). Both sets of prediction errors are well distributed around zero and show no significant trends.

The stock recruitment scatter plot (Figure 3.7.9) suggests that high values of recruitment have typically tended to occur at low values of SSB. Low recruitment has typically occurred at moderate and high levels of SSB suggesting that density dependent effects are potentially in operation (e.g. SSB inhibiting survival of juvenile scallops to recruitment age through limitations in suitable habitat).

Retrospective Analysis

The results of the retrospective analysis are shown in Figure 3.7.10. The addition of the 2010 data results in a revision of the estimates of recent fishing mortality and SSB, although this is less apparent between 2008 and 2009. Mean F is revised upwards while SSB is revised downwards. Revisions are also made to recruitment, but there does not appear to systematic under or over estimation.

State of the Stock

The state of the stock is summarised in Figure 3.7.6. The final estimates for the stock in 2010 are:

F(average over ages 4-6) = 0.367 yr^{-1}
SSB(total over ages 3-10+) = 622 t (muscle weight)

There are no reference points for this stock.

Estimates (and standard errors) of age-structured population abundance and fishing mortality are presented in Tables 3.7.7-3.7.10. Table 3.7.11 shows the stock summary. Fishing mortality on this stock is estimated to have increased markedly in 2010 to the highest value in the time series (although recent estimates are quite uncertain). The historical fishing mortality is estimated to have fluctuated between around 0.1 and 0.25. Recruitment has been fairly stable in recent years at around the long term average for the time series. SSB has been stable since the mid 2000s at above average levels.

Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2006 (Howell *et al.*, 2006) and presented the results of an assessment conducted using commercial data up to and including 2003 in a quarterly VPA tuned to average fishing mortality. This was updated in

2008 using data up to 2007 and a summary of stock status, including biomass trends can be found in the MSS Stock booklet (Scottish Government, 2010). For the current assessment, the commercial catch at age data series has been extended back in time and runs from 1986 onwards rather than from 1991 as in previous assessments. Trends in the time series of recruitment at age three from the current assessment are similar to those previously estimated but with a time lag of one year due to the differing ages at which recruitment has been estimated (previously age two). Trends in SSB and fishing mortality as estimated in the current assessment are broadly similar to those estimated previously Levels of mean F and SSB are not comparable to earlier estimates as mean F was previously calculated over ages six to eight (in the current assessment it is estimated for ages four to six) and SSB was previously presented as muscle plus gonad weight, whereas in the current assessment it is for muscle only.

NAFC Marine Centre also conduct stock assessments of the scallops around Shetland based on catch-at-age data obtained from their own commercial catch sampling. Leslie *et al*. (2009) use a quarterly VPA tuned using fishing effort data and including commercial data from 2000 to 2008. Estimates of total fishing mortality are of a similar magnitude to those estimated here and the trend in total numbers is also similar showing a peak in the mid 2000s. However, in terms of absolute value, numbers at age are quite different. The values estimated in this assessment are much greater than those estimated in the Leslie *et al.* (2009) assessment. This can be attributed to the differences in the raised commercial catch-at-age data used in the assessments. The total catch numbers used by Leslie *et al.* (2009) are significantly lower than MSS estimates. This appears to be due to differences in total landings as officially reported to MS (used by MSS) and those recorded by the SSMO (and used by NAFC). See discussion for further details.

3.7.6 Quality of the Assessment

Landings Data

Fishers are required to provide information about quantities landed and fishing location by ICES rectangle on either EU logbooks or Shell 1 forms (under 10 m vessels). The implementation of ‘the registration of buyers and sellers’ legislation in the UK in 2006 requires details of the landed catch also to be recorded at the point of first sale and sales notes are cross checked against vessels landings declarations. This procedure is thought to have improved the accuracy of reported landings data in recent years although there are unexplained anomalies with the SSMO data.

Age Composition

Scallop market sampling levels (the number of trips and number of scallops sampled) for Shetland have been consistently high since 1985 with only occasional un-sampled quarters.

Weights at Age

Mean muscle weights-at-age are now derived from a length-weight relationship (unpublished MSS) and the size at age composition data collected through the market sampling programme. This allows for inter-annual variation in weights-at-age (due to changes in size-at-age) to be accounted for in the estimate of SSB. Previously fixed values for weight-at-age were used.

Biological data on scallops from the Shetland area are collected and provided by staff from NAFC Marine Centre under the Memorandum of Understanding (MoU) between NAFC Marine Centre and MSS. It is intended that in advance of the next scallop assessments, these data will have been analysed to provide updated length-weight relationships.

Survey Data

On average, around 80 stations are sampled each year on the Shetland dredge survey, although in 2004, 2008 and 2009, poor weather substantially curtailed the survey. The Shetland assessment area is relatively small and has a significantly greater number of stations than other areas of comparable size. The survey stations are therefore at a much higher density across the fishing grounds than other areas. However, a number of important fishing areas are not surveyed. There are no survey stations located around the Outer Skerries and to the southeast of Whalsay, areas which have been fished regularly in recent years (according to VMS data).

The survey utilises a standard commercial dredge with large belly rings and a smaller laboratory dredge with small belly rings. Younger age classes (two and three year olds) have lower survey catchability because they are smaller in length and width and are able to pass through the belly rings of the dredge. However, occasional large catches are possible because other scallops and debris block their escape through the dredge which may result in variable catchability.

Model Formulation

TSA is useful in that it allows both fishing mortality and survey catchability to evolve over time in a constrained manner. It also allows for incomplete data series so that survey data with missing years (as is the case here) can be easily used.

3.7.7 Management Considerations

The VMS data for scallop vessels in the Shetland assessment area, suggests that fishing (at least by these larger vessels) occurs solely within the six mile limit of Shetland and is therefore licensed and managed under the SSMO.

SSB and recruitment currently appear relatively stable and above their long term average values. Fishing mortality has been above the long term average. In such circumstances advice is for no increase in fishing mortality.

3.8 East Coast

3.8.1 Description of the Fishery

The scallop fishery in the East Coast assessment area developed in the 1990s. There has been marked variability in the landings throughout the time period, from 299 t in 2001 to a high of over 2,500 t landed in 2007 (Figure 3.1.1). The East Coast scallop fleet consists of approximately twenty large vessels (15 to 22 m) which are mostly nomadic and fish from Peterhead down to Eyemouth. The fishery continues year round, but has a typical seasonal pattern with peak landings occurring in the second quarter. Vessels may work an area for a period of time before moving on, often returning to the same area the following year. Intense fishing has been known to occur off Bell Rock in the Firth of Forth and also on the scallop grounds further south off the coast of Burnmouth. Vessels land into Peterhead, Aberdeen, Gourdon, Montrose or Eyemouth, depending on which grounds they have been targeting.

3.8.2 Sampling Levels and Age Compositions

Sampling of the landings has been carried out since the beginning of the fishery (Table 3.8.1). A period of low sampling levels is apparent between 2001 and 2003 and is likely to be due to a lack of sampling opportunities given the low level of landings at this time. As landings increased in the mid 2000s, sampled numbers and trips also increased, but have declined again in 2009 and 2010. In 2010 only 6 trips and 1,287 individuals (across three quarters) were sampled.

Catch-at-age Data

Catch-at-age data for the East Coast are shown in Figure 3.8.1 for 1991 onwards. No specific age classes consistently dominate the landings and there are no apparent trends in age composition. The high landings in 1994-1995 consist mainly of young (ages 4-6) individuals from the 1989-1991 year classes, which dominate the landings in 1999 at older ages (8-10+).

3.8.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) available for scallops in the East Coast assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)
Muscle (annual)	0.00006386	2.668	MSS unpublished

The mean muscle weights are shown in Figure 3.8.2 and Table 3.8.3. There are no apparent systematic temporal trends although inter-annual fluctuations in mean weight at age are similar across age classes.

3.8.4 Exploratory Analysis

Catch Data

Catch curves by cohort for the commercial catch-at-age data are shown in Figure 3.8.3. On the whole, the catch curves are relatively noisy which is likely to be due to the often low levels of sampling, but also to the highly sporadic nature of the fishery. There are, however, some indications of relative year class strength, with the 1989 and 1999 year classes (recruitment in 1992 and 2002) appearing well above average and those of the mid 1990s being particularly low.

Survey Data

Details of the surveys which have been carried out in the East Coast assessment area are given in Table 3.6.4. A partial North Sea scallop survey was conducted in 1993, with full coverage of the East Coast assessment area beginning in 1994. Since 2001, the survey has been relatively consistent in terms of timing (June/July) and vessel. However, prior to this the survey was conducted towards the end of the year (September-December) and in one instance actually in the following calendar year (1998 survey conducted in January/February 1999). As in the west coast survey, no comparative tows have been conducted to compare catch rates between vessels and standardisation involves dividing the catch rate by dredge width to account for differences in the number of dredges worked.

The catch rates of scallops (all ages combined) at stations across the East Coast area between 2000 and 2010 are shown in Figure 3.8.4. During the early/mid 2000s, highest catch rates occurred in the offshore areas whilst more recently, the highest catch rates typically occur at the more inshore survey stations. Table 3.8.4 shows the average catch rates by age class and year. Catch rates by age class in this survey are generally < 5 individuals $hr^{-1}m^{-1}$ with only age five in 1994 having a catch rate much greater than this (~ 13 scallops $hr^{-1}m^{-1}$), further evidence for a strong year class in 1989. The year classes of 1998, 1999 and 2003 (recruitment in 2001, 2002 and 2006, respectively) also appear strong with above average catch rates across a range of age classes.

Catch curve analyses are shown in Figure 3.8.5 and show the survey index by age on the log scale for each cohort. The steeply increasing left hand limb of these curves indicates that the youngest age classes (ages two and three) have significantly lower survey catchability than older age classes and in fact catch rates of zero at age two are not uncommon (year classes 1996, 2001, 2004, 2006 and 2008). The cohort curves of 1998 to 2002 are relatively smooth showing good tracking of year classes (particularly the strong 1998 cohort) and consistent selection. Prior to this, the catch curves show increasing catch numbers through the cohort as it ages suggesting changes in the survey catchability of these age classes (compared to younger ages) through time.

3.8.5 Preliminary Assessment

The available commercial catch-at-age composition data are insufficient for an analytical assessment. A preliminary assessment of stock status is presented based on trends in survey data. Figure 3.8.6 shows mean standardised indices of SSB and recruitment from the survey. The SSB index is calculated as the sum of products of the catch rates at age and muscle weight at age for each year. Recruitment is given by the catch rate at age three.

A proxy for fishing mortality (exploitation rate) is calculated as the ratio of catch to survey SSB index.

The survey data show a doubling of SSB between the late 1990s and 2008 which appears to be largely due to the three strong year classes recruiting in 2001, 2002 and 2006. Evidence of a strong 2002 year class is also seen in the commercial catch data (see Section 3.8.4). Since 2007, recruitment has been low although the landings have remained at a fairly high level, resulting in a decline in SSB. The highly variable total landings are reflected in the estimates of exploitation rate (F proxy).

Comparison with Previous Assessments

Analytical assessments have not been conducted for the East Coast area. Survey data trends (in terms of a total catch rate and catch rates of individuals < 100 mm), up to 2004 were previously presented in Howell *et al.* (2006). The higher catch rates of small individuals (< 100 mm) in 2001-2003 and an increase in the total catch rate over this period are consistent with trends in the recruitment and SSB indices in the present assessment.

3.8.6 Quality of the Assessment

Landings Data

Fishers are required to provide information about quantities landed and fishing location by ICES rectangle on either EU logbooks or Shell 1 forms (under 10 m vessels). The implementation of ‘the registration of buyers and sellers’ legislation in the UK in 2006 requires details of the landed catch also to be recorded at the point of first sale and sales notes are cross checked against vessels landings declarations. This procedure is thought to have improved the accuracy of reported landings data in recent years.

Age Composition

Scallop market sampling levels (number of trips and number of scallops sampled) for the East Coast area have periodically been poor. The time series of catch composition data is therefore considered of insufficient quality for use in an analytic stock assessment. Some components of the dataset have however, been used to provide supportive qualitative information on, for example, relative year class strength.

Weights at Age

Mean muscle weights-at-age are now derived from a length-weight relationship (unpublished MSS) and the size at age composition data collected through the market sampling programme. This allows for inter-annual variation in weights-at-age (due to changes in size-at-age) to be accounted for in the estimate of SSB. Previously fixed values for weight-at-age were used.

Survey Data

Typically between 40 and 50 stations are sampled each year on the survey of the East Coast assessment area. The survey shows reasonable coverage of the scallop fishing grounds (inferred from VMS data), although station density is relatively low (compared to, for example, Shetland) particularly in the offshore areas between Fife and Montrose.

The survey utilises a standard commercial dredge with large belly rings and a smaller laboratory dredge with small belly rings. Younger age classes (two and three year olds) have lower survey catchability because they are smaller in length and width and are able to pass through the belly rings of the dredge. However, occasional large catches are possible because other scallops and debris block their escape through the dredge which may result in variable catchability.

Model Formulation

No analytical assessment model is used. The assessment is based on trends in survey catch rates.

3.8.7 Management Considerations

Although no formal analytic assessment has been carried out for the East Coast area, it is clear from the stock trends evident in the survey data analysis that the fishery in this area is sporadic and dependent on a few strong year classes. In the long term the area is therefore unlikely to be able to continue to support landings at the levels recently seen.

3.9 Orkney

3.9.1 Description of the Fishery

The Orkney scallop fishery began in the 1970s but has remained relatively small in comparison to other assessment areas. There are approximately six local dredgers (some of which also fish with nets and creels) and twelve dive boats that fish grounds in Scapa Flow, Bay of Firth and around the northern isles of Orkney and other sites locally.

3.9.2 Sampling Levels, Age Compositions

Very limited sampling of recent landings was achieved in this fishery: a total of 3,992 scallops were measured during 2007-2010 (Table 3.9.1). There are insufficient data for assessment purposes.

Catch-at-age Data

There are some catch-at-age data raised to Scottish landings for the Orkney area available in FMD from the early 1990s. However, these are based on a very low numbers of samples and are not considered of sufficient quality for further analysis.

3.9.3 Biological Data

The parameters of the length-weight relationships (Weight (g) = a x Length (mm) ^{b}) available for scallops in the Orkney assessment area are as follows:

	a	b	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)
Muscle (annual)	0.00007599	2.668	MSS unpublished

3.9.4 Assessments

The available data are insufficient for an analytical assessment and there are no surveys of this area.

4. General Discussion

4.1 Regional Summaries

Substantial scallop fisheries have existed around the coast of Scotland for many years. In some areas, such as the Irish Sea, Shetland and Orkney there are systematic increases apparent in the landings data. However, in other areas (North West and North East), the landings are characterised by occasional and rapid increases or declines. Some of these are associated with fishery closures due to ASP/PSP toxins, but others appear to be due to the appearance of strong year classes (increases in recruitment).

The TSA stock assessments show that following periods of high recruitment during the mid 1990s, both of the main west coast stocks of scallops have experienced poorer levels of recruitment in recent years which has resulted in declining biomass. The continued high catches in the West of Kintyre are reflected in the recent increase in fishing mortality, although the estimates of fishing mortality are relatively uncertain. In contrast, the lower catches from the North West have resulted in a lower estimate of fishing mortality in this area.

To the north east of Scotland (North East and Shetland assessment areas), recruitment is estimated to have been strong during the early 1990s, coinciding with increased catches, and more moderate in recent years. The fishing mortality (as estimated in the TSA) in these areas increased during the late 1980s and in Shetland has increased again in recent years concomitant with the increases in catches.

Although no analytical assessment has been presented for the East Coast area, stock trends based on the dredge survey data suggest that SSB increased during the 2000s following a number of strong year classes. More recent recruitment appears to have been low and SSB is declining.

Historical stock trends estimated by the TSA approach show good agreement with previous scallop assessments presented in the MSS stock booklet (Scottish Government, 2010). The absolute levels of biomass, recruitment and fishing mortality presented here are not directly comparable with previous assessments as different measures have been used to define these quantities (e.g. recruitment at age three compared with recruitment at age two previously).

The stock recruitment plots provided for the four areas assessed using TSA show little evidence of a stock recruitment relationship. One explanation for this may be that recruitment is truly independent of stock size (although others have observed density dependent effects, Vahl, 1982) and is driven more by external factors such as environmental conditions, which are not included in the model. Another is that the model estimates of SSB (individuals aged three and above) are not a good measure of spawning potential as two year old individuals are also mature but are not included in the model. The lack of a clear stock recruit relationship has implications for the type of stock projections that could be carried out for scallop stocks. Although short term projections typically make use of recent average recruitment, the simulations that would be required to investigate the medium to long term effects of changes in, for example, minimum landing size (MLS) typically require the use of a stock recruit relationship. An alternative method for modelling future recruitment in a stock which exhibits sporadic recruitment (North Sea haddock) is presented in Needle (2008). The method generates random recruitment from a lognormal distribution with additional occasional very strong year classes. Assumptions about the distribution and frequency and size of high year classes are derived from the historical time series. Such an approach may prove useful in any scallop management strategy evaluations that are required in the future.

4.2 Reference Points

There are currently no agreed biomass or fishing mortality reference points for Scottish scallop stocks. Stock status and management considerations are therefore provided on the basis of a comparison of estimates of current fishing mortality, recruitment and biomass in relation to historical values. The lack of a stock recruitment relationship precludes the calculation of target reference points based on maximum sustainable yield. In cases where F_{MSY} cannot be estimated directly, proxy values based on per recruit analysis are often used (ICES, 2010). ICES has advised on the use of F_{MAX} (fishing mortality at the maximum of the yield per recruit (YPR) curve) as an appropriate proxy unless there is evidence of poor recruitment at such levels of fishing mortality. In cases where the maximum of the YPR curves is less well defined then $F_{0.1}$ (fishing mortality at which the slope of the YPR curve is 10 % of the slope at the origin) or reference points based on spawning biomass per recruit are likely to be more appropriate proxies.

The ICES advice framework also makes use of biomass reference points which are used as limits rather than targets. For many ICES fish stocks, B_{lim} (limit reference point for biomass) has been defined as the historical lowest observed spawning stock (B_{loss}) – the value below which recruitment is expected to be 'impaired' or the stock dynamics are unknown. The precautionary reference point (B_{PA}) is derived from this value by adjusting it to account for variability and uncertainty in the assessment.

Scallop (*Placopecten magellanicus*) stocks off the north east US coast are managed in relation to a target fishing mortality of 80 % of F_{MAX} (used as a proxy for F_{MSY}). A proxy for B_{MSY} on the basis of the product of B_{MAX} (biomass per recruit at F_{MAX}) and the median number of recruits per tow from the survey is also used (SAW Invertebrate Subcommittee, 2004). The threshold for being in an 'overfished condition' is defined as half of B_{MAX}. In New Zealand, $F_{0.1}$ is used as a target fishing mortality in the major scallop (*Pecten novaezelandia*e) fisheries (New Zealand Government, 2011). However, they state that biomass reference points based on virgin biomass or B_{MSY} are not likely to be appropriate for stocks with highly variable recruitment and growth.

There are clearly a number of options to be explored for the calculation of reference points for Scottish scallop stocks. The calculation of fishing mortality reference points based on per recruit curves would be relatively straightforward given that the required inputs for the calculations are a direct output from the TSA assessment. In addition, there is a relatively long time series of abundance estimates (either the TSA output or from the surveys) that could potentially be used to derive biomass reference points. It is anticipated that potential reference points will investigated ahead of MSS' next round of assessments to be carried out in 2013.

4.3 Comments on the Quality of the Data and Assessment

The age-structured TSA analytical assessment method used in this report is considered to be an improvement on the methods previously used. It provides more robust estimates of stock status as it makes use of multiple data sources (commercial catch-at-age and survey indices by age) and can cope with the omission of poor quality or missing data. In addition, the estimates of abundance and fishing mortality are calculated with confidence intervals. The accuracy and precision of the estimates of stock status depend on the quality of both the total commercial catch-at-age data and the survey indices at age. The catch-at-age data are derived from length and age structured data sampled by MSS staff which are then raised to total official landings data[1]. The introduction of buyers and sellers legislation in 2006 is thought to have improved the accuracy of reported landings, although given that Scottish scallop fisheries are not regulated through TACs there is actually no incentive for fishers to underreport or misreport scallops. When preparing data for this report we found some inconsistencies between the Shetland area landings as reported to the SSMO and those officially reported to MS. Despite a thorough investigation, the source of these discrepancies could not be traced. Underreporting to the SSMO may have been a factor in the past, but in recent years there has been 100 % compliance in terms of logsheet returns (Leslie, *personal communication*). Skippers may use a nominal bag weight rather than actually weighing their catch for their EU logsheets, but cross-checks with the sales notes (completed by processors) should limit biases in these data (MS data). These inconsistencies result in estimates of population size which appear to differ by a scaling factor (fishing mortalities quite similar) and therefore conclusions regarding stock status from the NAFC stock assessments and those presented here are broadly similar.

There are insufficient age composition samples from the Clyde, East Coast, Irish Sea and Orkney to perform analytic stock assessments. The Clyde, East Coast and Orkney have historically been less important scallop fishery areas although landings from the East Coast have increased recently. The unpredictable nature of these fisheries makes the acquisition of landings samples particularly difficult. The Irish Sea is the most important of the scallop assessment areas in terms of total landings, but over half of these are landed into ports outside Scotland. Samples from Scottish ports are therefore unlikely to be representative of the fishery as a whole. A collaborative programme of work (UK and Isle of Man) to cover sampling and stock monitoring may improve the basis for assessment and advice in this area.

In other areas for which we have conducted analytical assessments, sampling levels have typically fallen in recent years due to limited resources within MSS. Although a single year with poor sampling levels may not significantly affect the conclusions of the assessment, continued poor sampling levels are likely to result in less precise, and potentially biased,

[1] Length at age data and sampled weights for dredge and dive caught scallops are combined and raised to total dredge landings on a quarterly basis. Changes to FMD which will enable these samples to be raised separately to dive and dredge landings for future stock assessments are anticipated.

results. In an attempt to improve shellfish sampling levels, MS Compliance staff have recently been trained to take part in market sampling in a variety of locations around the Scottish coast. In addition, there are moves within MSS to redesign and/or more appropriately target sampling effort across shellfish stocks.

The survey data are an integral component of the stock assessment and provision of advice on stock status and for the East Coast are currently the only source of information. The surveys show reasonably good coverage of the fished areas according to scallop dredge VMS data with the exception of the West of Kintyre where there are a number of areas with apparently high fishing effort which are not surveyed. The density of stations is greatest in Shetland. It is not clear whether this is required to retain a particular level of precision in the survey abundance index estimates or whether there is potential to redistribute survey effort. In the stock assessments of the west coast, particularly for the West of Kintyre, the residuals of the model fits to data suggests that there was a change in the survey catchability at older ages during the late 1990s and early 2000s. It is not clear whether this is due to changes in actual survey catchability or whether this mismatch between the survey and catch data is a result of changes in the distribution of stock and fishery in relation to the survey. The retrospective analyses which illustrate how the final year estimates change with the inclusion of an additional year's data also show patterns which are consistent with changes in catchability (estimates of recruitment are revised downwards on an annual basis).

The outputs from the stock assessment are presented in terms of muscle weight. These are calculated from numbers at age by the use of mean muscle weights-at-age derived from a length-weight relationship and the size at age composition data collected through the market sampling programme. The source of the regional length-muscle weight relationships in FMD is not documented, but it is believed that the relationships have not been updated for a number of years. Revisiting these length-weight relationships for all assessment areas would be a major undertaking but could potentially provide more reliable estimates of spawning stock biomass. Biological data on scallops from the Shetland area are already being collected and provided by staff from NAFC Marine Centre under the Memorandum of Understanding (MoU) between NAFC Marine Centre and MSS. It is intended that in advance of the next scallop assessments, these data will have been analysed to provide updated length-weight relationships.

The population structure of Scottish scallop stocks is not well understood, and the assessment areas were defined to reflect the characteristics of the fisheries in the past rather than on the basis of evidence to support discrete populations. Similar trends in recruitment across the West of Kintyre and North West and also in Shetland, the North East and East Coast suggest that there are linkages between some of these areas at pre-recruitment stages with similar trends in survival to age of recruitment. Adult scallops are relatively sedentary and able to swim only limited distances. Larvae, however, inhabit the water column for three weeks or more, during which time they may drift a substantial distance (dependent on water circulation, tides and wind driven currents) from the parent population before settling to the sea bed. There is therefore potential for population linkage across substantial distances. Habitats suitable for scallops are patchily distributed and some patches of adult population may provide a source of larvae for others. MASTS (Marine Alliance for Science and Technology for Scotland) have recently funded a project to investigate the impact of marine reserves and wind-farm developments on scallop stocks. As part of this work a model will be developed which will simulate the dispersal patterns of scallop larvae using the outputs of ocean circulation models and link these with models of growth, survival and spawning of individuals following settlement. This should provide further information about the magnitude and scale of connectivity between scallop populations around Scotland which may have implications for the areas on which the assessments are based.

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6. Glossary

Fishing mortality: describes the rate of removal of fish from the stock due to fishing activities using any fishing gear. Technically it is defined as the proportion of the stock removed in a small unit of time (instantaneous) or the fraction of the average population removed by fishing. Abbreviated to F.

Fortran: a computer programming language used particularly for computationally intensive jobs.

ICES: The International Council for the Exploration of the Sea promotes marine research on oceanography, the marine environment and marine resources in the North Atlantic. A global network of scientists work through ICES to provide unbiased, non-political advice on the marine environment, including the exploitation of fish stocks.

Kalman filter: An algorithm that makes use of a series of noisy observations to obtain an estimate of an unknown variable.

R: An open source programming language and software environmental for statistical computing and graphics.

Spawning stock biomass: The total weight of the fish in a stock that are old enough to spawn; the biomass of all fish beyond the age or size class in which 50% of the individuals are mature. Abbreviated to SSB.

Virtual Population Analysis: A method commonly used for stock assessment by fisheries scientists to reconstruct historical fish numbers at age using information on the removal of individuals each year due to fishing and natural mortality. Abbreviated to VPA.

7. Tables

Table 2.1.1

Scottish scallop assessment areas.

Name	Statistical Rectangles
Irish Sea	35-37 E3-E7; 38 E4-E6
Clyde	39-40 E5; 40 E4 (eastern half)
West of Kintyre	39-40 E2-E3; 39 E4; 40 E4 (western half); 41 E4
North West	41-46 E1-E3; 42-46 E4
Orkney	47 E4; 46-47 E5-E6; 47 E7
Shetland	48-51 E7-E9
North East	44 E5-E8; 45 E6-E9; 46 E7-E9; 47 E8-E9
East Coast	39-43 E8-F0; 40-41 E6; 40-43 E7; 44 E9-F0

Table 3.1.1

Scottish (UK vessels into Scotland) dredge landings (tonnes) 1982-2010.

	West of Kintyre	North East	North West	Clyde	Irish Sea	Orkney	East Coast	Shetland	Total
1982	1510	672	3173	102	340	42	5	422	6267
1983	1234	645	2035	68	266	29	0	357	4634
1984	1677	403	2220	132	594	22	0	402	5450
1985	913	388	1524	180	538	4	0	212	3759
1986	688	559	1437	76	270	109	0	362	3500
1987	883	679	1670	92	415	120	1	311	4171
1988	469	671	1608	79	594	35	0	359	3815
1989	577	894	1581	31	450	293	1	537	4364
1990	620	952	1357	18	451	176	2	447	4023
1991	617	385	1104	48	374	124	540	405	3598
1992	781	1733	1070	23	234	26	321	534	4722
1993	1014	1571	976	75	314	0	626	530	5105
1994	1073	2322	1845	182	242	110	1813	603	8191
1995	890	3150	1366	139	410	214	1902	743	8814
1996	1154	3490	2037	110	605	214	679	674	8964
1997	1360	2943	2300	231	397	146	715	932	9024
1998	1528	1739	2698	243	682	163	1006	920	8979
1999	1188	1682	1087	201	1039	291	1819	748	8055
2000	1630	1512	3337	352	458	99	726	338	8451
2001	1069	1736	4132	304	732	442	299	492	9205
2002	1308	738	4261	473	637	268	416	558	8659
2003	1410	1814	3441	508	634	175	818	757	9556
2004	1026	1958	3163	541	751	148	2439	894	10921
2005	1021	2025	2517	415	839	220	1571	720	9328
2006	785	1795	1135	387	733	117	1769	772	7494
2007	974	1333	1300	300	831	104	2593	858	8293
2008	1383	1385	2201	439	894	184	1843	880	9209
2009	1092	2155	1318	451	1450	192	1528	915	9100
2010	1305	1267	1134	528	1461	176	1757	1071	8698

Table 3.1.2
Diver caught landings (tonnes) in Scotland, 1982-2010.

	West of Kintyre	North East	North West	Clyde	Irish Sea	Orkney	East Coast	Shetland	Total
1982	83	12	163	5	0	7	0	1	270
1983	106	4	303	3	0	38	0	0	453
1984	59	0	388	11	0	98	0	0	557
1985	63	0	310	0	0	71	0	0	444
1986	94	17	299	0	0	35	0	6	451
1987	105	1	426	0	0	46	0	0	579
1988	88	5	244	0	0	49	0	1	388
1989	59	1	170	1	0	74	0	0	304
1990	41	3	83	0	0	57	0	0	184
1991	47	0	175	0	0	70	0	21	312
1992	47	0	199	0	0	87	0	1	334
1993	48	0	171	0	0	36	0	47	302
1994	120	0	157	1	0	92	0	27	397
1995	38	2	453	0	0	222	0	22	737
1996	109	3	287	0	0	150	0	0	550
1997	128	1	481	0	0	139	1	0	750
1998	135	0	394	0	0	176	0	6	711
1999	62	0	150	0	0	162	0	7	381
2000	18	4	142	0	0	162	0	0	325
2001	113	9	244	15	0	126	0	0	507
2002	50	3	272	37	0	117	0	14	492
2003	59	0	296	18	0	113	0	4	490
2004	43	0	118	27	0	87	0	0	274
2005	43	3	134	42	0	172	0	0	393
2006	52	6	196	11	0	100	0	0	365
2007	48	0	230	4	0	80	0	0	363
2008	56	1	162	37	0	89	0	0	346
2009	60	3	205	24	0	101	0	0	392
2010	73	1	228	6	0	125	0	0	433

Table 3.1.3

Landings (tonnes) into the UK (excluding Scotland), Ireland and the Isle of Man. No UK (non Scotland) data available prior to 2000 for East Coast, North East and West of Kintyre assessment areas. Shaded cells filled in on basis of average proportions (2000-2010) of UK total for use in stock assessments. '+' denotes landings of < 0.5 tonnes.

	England, Wales & N. Ireland				Ireland	Isle of Man
	East Coast	Irish Sea	North East	West of Kintyre	West of Kintyre	Irish Sea
1982	**+**	581	**+**	**126**		1402
1983	**+**	523	**+**	**106**		1368
1984	**+**	457	**+**	**137**		1977
1985	**+**	328	**+**			2162
1986		575	**+**	**62**		1508
1987	**+**	485	**+**	**78**		1833
1988		609	**+**	**44**		1230
1989	**+**	846	**1**	**50**		1047
1990	**+**	447	**1**	**52**		916
1991	**14**	403	**+**	**52**		898
1992	**9**	373	**1**	**65**		633
1993	**16**	373	**1**	**84**		645
1994	**47**	560	**2**	**95**		931
1995	**49**	403	**2**	**73**		931
1996	**17**	656	**2**	**100**		1064
1997	**18**	975	**2**	**118**		932
1998	**26**	1418	**1**	**131**		705
1999	**47**	1496	**1**	**99**		794
2000	18	1078		73		965
2001	14	1373		58		1116
2002	62	1070	6	95		1093
2003	12	1029	+	54		1105
2004		874	+	98		1106
2005	6	1026		101		1016
2006	24	754		67		1522
2007	27	1319		85		1201
2008	20	1559		84		1453
2009	9	2134		226	+	1434
2010	10	1892		95	+	1641

Table 3.1.4

Total landings (tonnes) from Scottish assessment areas 1982-2010, as used in the assessments (includes landings into UK, Ireland and the Isle of Man). Note that estimated Irish Sea landings prior to 2000 may include a small amount of landings from elsewhere in ICES Sub-area VIIa (i.e. from outside the Irish Sea assessment area).

	West of Kintyre	**North East**	**North West**	**Clyde**	**Irish Sea**	**Orkney**	**East Coast**	**Shetland**	**Total**
1982	1718	685	3336	107	2323	49	5	423	**8647**
1983	1446	650	2338	71	2157	67	0	357	**7085**
1984	1873	403	2608	143	3030	121	0	402	**8580**
1985	1053	388	1834	180	3031	76	2	212	**6776**
1986	844	577	1735	78	2354	143	0	368	**6099**
1987	1066	681	2096	92	2734	169	1	311	**7150**
1988	601	677	1852	79	2433	84	0	360	**6087**
1989	686	895	1752	32	2343	367	2	537	**6614**
1990	714	956	1447	18	1814	237	4	449	**5639**
1991	716	385	1288	48	1675	194	560	426	**5292**
1992	893	1734	1270	23	1240	113	340	535	**6148**
1993	1146	1572	1148	77	1332	36	643	577	**6530**
1994	1292	2327	2010	184	1733	202	1865	634	**10247**
1995	1002	3155	1820	139	1744	436	1953	765	**11015**
1996	1364	3500	2324	111	2325	365	697	675	**11360**
1997	1605	2949	2781	231	2304	285	738	932	**11825**
1998	1795	1740	3096	243	2805	340	1032	926	**11977**
1999	1349	1683	1255	201	3330	455	1865	755	**10894**
2000	1721	1516	3481	352	2501	260	744	338	**10913**
2001	1250	1800	4376	319	3221	572	312	496	**12345**
2002	1453	748	4533	510	2800	385	478	572	**11480**
2003	1552	1814	3758	528	2768	291	830	764	**12305**
2004	1174	1965	3297	574	2731	243	2445	895	**13324**
2005	1166	2028	2656	456	2881	393	1580	720	**11881**
2006	908	1829	1356	400	3010	226	1806	776	**10310**
2007	1108	1338	1532	305	3351	203	2745	861	**11444**
2008	1541	1395	2407	481	3911	285	1936	880	**12836**
2009	1386	2159	1548	484	5058	298	1642	915	**13489**
2010	1478	1274	1365	534	5030	314	1791	1072	**12858**

Table 3.2.1

West of Kintyre: Quarterly dredge landings (UK vessels into Scotland) and sampling levels, 1982-2010.

	Landings (tonnes)					**Numbers Aged and Measured/Boats Sampled**			
	Qtr1	**Qtr2**	**Qtr3**	**Qtr4**	**Total**	**Qtr1**	**Qtr2**	**Qtr3**	**Qtr4**
1982	583	368	301	258	1510	4239/19	1421/7	0	1764/4
1983	353	447	198	237	1235	178/1	356/2	557/2	3794/22
1984	405	552	365	355	1677	864/5	642/4	576/3	308/19
1985	296	300	147	170	913	2925/17	1300/7	3565/19	1655/9
1986	187	229	133	138	687	4888/29	1803/10	1545/8	1930/8
1987	304	225	209	144	882	2391/10	1494/8	1466/7	1244/6
1988	159	134	61	116	469	1899/9	1818/9	265/1	1624/7
1989	135	126	153	165	578	471/2	914/4	2268/7	2555/8
1990	161	60	169	230	620	1063/4	2360/9	3532/15	6091/24
1991	204	152	138	123	617	5038/23	7950/32	6408/23	5991/24
1992	151	216	187	225	780	2841/14	2487/12	6016/23	6229/18
1993	166	269	221	357	1013	3173/12	4580/16	3581/13	5827/23
1994	290	322	173	288	1073	6834/29	1212/9	5669/21	4753/20
1995	153	192	215	330	890	5843/22	2164/8	1500/6	1966/7
1996	283	329	280	262	1154	4612/18	2309/9	2306/9	2752/11
1997	379	218	257	506	1360	3142/12	765/4	2498/9	1288/5
1998	459	308	279	482	1528	2469/10	2311/9	1538/7	3584/16
1999	314	335	374	165	1188	1385/5	1727/8	1440/6	1475/7
2000	174	489	442	525	1630	1280/6	3176/15	1251/6	3340/15
2001	367	331	192	180	1070	3239/15	2145/10	1680/9	1234/6
2002	315	261	314	417	1307	2453/12	1026/5	930/5	1654/8
2003	331	335	397	347	1410	1605/8	1553/8	2543/14	2724/15
2004	313	216	205	292	1026	1608/7	173/1	703/4	1434/9
2005	258	277	174	312	1021	2508/16	1607/8	1537/7	486/3
2006	257	167	140	220	784	527/3	379/2	467/3	0
2007	270	243	192	270	975	918/6	1242/6	1538/7	694/4
2008	278	581	214	310	1383	1557/8	634/4	1888/9	538/3
2009	337	287	196	270	1090	1207/6	1833/9	1695/7	1214/5
2010	341	276	284	404	1305	145/1	663/3	792/4	524/2

Table 3.2.2

West of Kintyre: Total catch-at-age numbers (in thousands).

	2	3	4	5	6	7	8	9	10+
1982	570	1184	1050	746	878	1011	928	869	1914
1983	34	905	1287	1026	815	1030	1104	909	1339
1984	155	877	1274	1537	1307	1298	1072	580	1521
1985	184	465	641	652	580	600	614	517	1227
1986	74	381	527	567	584	434	409	429	1099
1987	217	982	893	877	781	488	377	299	958
1988	29	378	416	430	309	336	324	293	769
1989	1146	787	595	578	378	132	209	138	371
1990	194	1350	618	548	409	328	285	120	299
1991	115	614	1021	406	350	319	267	163	562
1992	28	483	1429	1142	515	307	302	240	695
1993	115	1408	1947	1217	775	373	255	180	407
1994	10	363	1508	1768	1111	609	361	172	1023
1995	17	823	1439	1298	785	449	185	82	407
1996	6	1287	2288	1564	1098	628	356	187	456
1997	24	1678	2531	1485	1298	838	433	303	451
1998	7	560	2260	2043	1806	1440	793	340	625
1999	16	932	2036	1712	868	660	498	250	578
2000	0	837	1946	1905	1433	1215	803	518	738
2001	0	35	1125	1636	1060	767	614	485	845
2002	1	168	1147	2251	1529	1045	718	527	550
2003	4	735	2951	1489	1317	781	613	407	609
2004	28	640	1375	2074	797	672	404	159	457
2005	5	686	1564	1471	1076	586	365	164	327
2006	0	28	1745	1395	859	518	319	174	92
2007	1	337	1287	1293	987	919	580	236	227
2008	11	466	1219	1965	1955	1208	721	369	200
2009	0	672	1819	1488	1723	1126	640	293	512
2010	0	1181	2297	2139	1325	718	469	216	491

Table 3.2.3

West of Kintyre: Mean weights-at-age (muscle) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1982	0.014	0.017	0.019	0.020	0.024	0.025	0.028	0.029	0.033
1983	0.011	0.014	0.017	0.018	0.019	0.020	0.022	0.025	0.029
1984	0.011	0.015	0.019	0.022	0.024	0.025	0.026	0.028	0.031
1985	0.013	0.016	0.019	0.022	0.023	0.024	0.025	0.026	0.028
1986	0.012	0.014	0.017	0.020	0.023	0.024	0.024	0.025	0.028
1987	0.012	0.015	0.018	0.021	0.023	0.025	0.026	0.027	0.029
1988	0.012	0.015	0.016	0.020	0.021	0.023	0.025	0.026	0.028
1989	0.014	0.016	0.018	0.020	0.022	0.025	0.025	0.026	0.029
1990	0.012	0.016	0.019	0.022	0.024	0.025	0.026	0.028	0.032
1991	0.013	0.016	0.020	0.022	0.024	0.025	0.027	0.028	0.031
1992	0.014	0.015	0.016	0.020	0.023	0.025	0.026	0.027	0.030
1993	0.013	0.015	0.018	0.022	0.024	0.027	0.028	0.028	0.030
1994	0.015	0.016	0.017	0.019	0.022	0.026	0.028	0.029	0.033
1995	0.016	0.017	0.019	0.022	0.024	0.027	0.029	0.030	0.030
1996	0.013	0.016	0.018	0.021	0.023	0.026	0.028	0.029	0.030
1997	0.014	0.016	0.019	0.022	0.024	0.026	0.027	0.029	0.027
1998	0.011	0.016	0.018	0.020	0.022	0.025	0.026	0.028	0.029
1999	0.015	0.017	0.018	0.021	0.024	0.026	0.027	0.028	0.029
2000	0.014	0.016	0.019	0.020	0.023	0.024	0.026	0.028	0.031
2001	0.013	0.015	0.018	0.021	0.023	0.025	0.026	0.026	0.028
2002	0.016	0.017	0.018	0.020	0.023	0.024	0.025	0.026	0.029
2003	0.015	0.016	0.017	0.019	0.023	0.025	0.027	0.028	0.031
2004	0.015	0.017	0.018	0.020	0.023	0.025	0.028	0.029	0.030
2005	0.017	0.017	0.020	0.021	0.023	0.026	0.030	0.031	0.035
2006	0.016	0.014	0.017	0.019	0.024	0.027	0.030	0.034	0.034
2007	0.017	0.016	0.019	0.022	0.024	0.024	0.027	0.032	0.032
2008	0.014	0.015	0.018	0.021	0.023	0.026	0.029	0.033	0.036
2009	0.015	0.016	0.017	0.018	0.020	0.023	0.025	0.026	0.030
2010	0.015	0.016	0.018	0.019	0.021	0.023	0.025	0.027	0.030

Table 3.2.4

Summary of Marine Scotland Science West Coast scallop dredge surveys 1988-2010. Data from greyed out surveys are not used in the assessment.

Vessel	Cruise dates		Dredge type	No. of dredges	Width (m)	No. of hauls		No. of scallops
	From	To				WK	NW	
R.V. Goldseeker	08-Jun-88	12-Aug-88	A B	2 1	2.25	115		3543
R.V. Goldseeker	10-Jun-89	13-Jul-89	A B	2 1	2.25	94		2124
R.V. Aora	14-Jun-90	30-Jun-90	A B	3 3	4.5	85		4951
R.V. Aora	15-Jun-92	03-Jul-92	A B	3 3	4.5	103		7671
R.V. Aora	21-Jun-93	09-Jul-93	A B	3 3	4.5	31	78	11989
R.V. Aora	20-Jun-94	08-Jul-94	A B	3 3	4.5	25	88	12068
R.V. Aora	19-Jun-95	07-Jul-95	A B	3 3	4.5	25	92	10807
R.V. Aora	17-Jun-96	05-Jul-96	A B	3 3	4.5	26	85	10124
R.V. Aora	16-Jun-97	04-Jul-97	A B	3 3	4.5	24	79	9813
R.V. Aora	15-Jun-98	03-Jul-98	A B	3 3	4.5	24	88	11561
R.V. Aora	14-Jun-99	30-Jun-99	A B	3 3	4.5	26	90	10373
R.V. Aora	12-Jun-00	30-Jun-00	A B	3 3	4.5	28	84	12073
R.V. Aora	09-Jul-01	27-Jul-01	A B	3 3	4.5	26	96	11180
F.V. Golden Promise	20-May-02	30-May-02	A A	10 10	15	15	61	11124
R.V. Aora	10-Jun-02	26-Jun-02	A B	3 3	4.5	26	83	11259
R.V. Aora II	04-Aug-03	22-Aug-03	A B	6 6	9	24	78	21134
R.V. Aora II	09-Aug-04	27-Aug-04	A B	6 6	9	24	76	18963
R.V. Aora II	08-Aug-05	27-Aug-05	A B	6 6	9	23	74	17912
R.V. Aora II	07-Aug-06	26-Aug-06	A B	6 6	9	23	82	22190
R.V. Aora II	21-May-07	07-Jun-07	A B	6 6	9	22	75	13404
R.V. Alba na Mara	24-Apr-08	15-May-08	A B	6 6	9	22	70	12608
R.V. Alba na Mara	19-Apr-09	08-May-09	A B	6 6	9	22	69	13817
R.V. Alba na Mara	02-Apr-10	20-Apr-10	A B	6 6	9	21	68	12293

Dredge Type A: Standard commercial dredge. 2.5' wide. 9 tooth bar. Large belly rings.
Dredge Type B: Laboratory sampling dredge. 2.5' wide. 11 tooth bar. Small belly rings.

Table 3.2.5

West of Kintyre: Available research-vessel survey data (numbers hour^{-1}metre^{-1} by age class and year).

	2	3	4	5	6	7	8	9	10+
1993	0.82	10.65	10.01	5.95	4.41	1.85	1.24	1.12	3.48
1994	0.13	4.30	13.52	9.84	4.73	3.70	1.23	0.78	2.21
1995	0.40	10.12	11.62	8.88	4.34	2.14	1.19	0.54	1.70
1996	0.12	4.14	9.11	7.15	5.49	2.79	1.37	0.96	2.11
1997	0.24	5.69	12.58	9.59	5.81	3.71	1.78	0.92	1.70
1998	0.21	7.88	11.71	9.98	5.95	4.37	2.14	1.20	1.65
1999	0.05	4.59	6.80	7.14	5.37	4.27	3.26	1.82	1.96
2000	0.05	6.63	13.23	8.58	5.82	4.16	2.83	1.49	1.45
2001	0.80	2.19	10.23	8.28	4.24	2.65	2.02	1.22	1.88
2002	0.02	9.91	5.13	10.23	7.60	3.45	2.42	1.23	4.31
2003	0.42	5.61	13.01	4.90	6.12	3.06	1.93	1.61	2.25
2004	1.18	5.28	6.35	9.71	3.56	3.84	2.12	1.62	2.44
2005	0.15	9.75	10.00	6.77	6.17	3.34	2.27	1.48	2.13
2006	0.04	4.39	9.80	12.55	8.68	4.90	3.83	2.38	2.35
2007	0.02	2.19	8.02	8.45	7.75	4.99	3.47	2.72	3.72
2008	0.07	2.12	5.67	7.07	5.69	3.92	2.02	1.45	2.06
2009	0.07	4.61	14.12	8.99	5.01	3.31	2.33	0.74	4.63
2010	0.03	10.35	15.16	8.80	3.98	2.32	1.05	0.26	4.29

Table 3.2.6

West of Kintyre: Final TSA run parameter estimates.

Parameter	Notation	Description	2011
Initial fishing mortality	F(3, 1982)	Fishing mortality at age a in year y	0.12
	F(4, 1982)		0.16
	F(6, 1982)		0.16
Survey selectivities	$\Phi(3)$	Survey selectivity at age a	0.06
	$\Phi(4)$		0.13
	$\Phi(5)$		0.15
	$\Phi(6)$		0.15
	$\Phi(7)$		0.16
	$\Phi(8)$		0.17
	$\Phi(9)$		0.17
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0.00
	σ_U	Persistent changes in selection (age effect in F)	0.16
	σ_V	Transitory changes in the year effect in F	0.03
	σ_Y	Persistent changes in the year effect in F	0.20
Survey catchability standard deviations	σ_Ω	Transitory changes in survey catchability	0.00
	σ_β	Persistent changes in survey catchability	0.13
Measurement coefficients of variation	cv landings	Coefficient of variation of landings-at-age data	0.27
	cv survey	Coefficient of variation of survey data	0.31
Recruitment	η^2	Mean	10.19
	cv rec	Coefficient of variation of recruitment curve	0.22

Table 3.2.7

West of Kintyre: Estimated population abundance by age and year (in thousands) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	11935	9121	8052	7492	5850	5246	4325	7462
1983	9526	9301	6926	6067	5300	4059	3635	7996
1984	8232	7346	6888	5045	4119	3582	2721	7773
1985	7597	6237	5252	4732	3144	2554	2223	6517
1986	7782	5914	4645	3780	3176	2110	1715	5867
1987	7620	6109	4458	3383	2599	2184	1452	5209
1988	5557	5729	4478	3133	2295	1766	1484	4523
1989	6274	4239	4264	3271	2230	1632	1256	4270
1990	9999	4734	3113	3087	2438	1664	1212	4104
1991	10909	7619	3421	2181	2265	1802	1228	3929
1992	11865	8611	5526	2414	1557	1636	1313	3755
1993	14157	9413	5999	3683	1643	1052	1120	3498
1994	13338	11223	6494	3993	2507	1117	715	3171
1995	14453	10597	7866	4193	2476	1546	689	2408
1996	14631	11654	7762	5494	2855	1686	1053	2106
1997	14025	11537	8277	5315	3634	1891	1115	2088
1998	12396	11029	8006	5602	3372	2332	1211	2034
1999	12498	9798	7577	5217	3355	1991	1374	1887
2000	12215	10047	6930	5055	3449	2220	1319	2158
2001	9099	9796	6968	4320	2806	1919	1234	1930
2002	12611	7437	7082	4552	2555	1654	1137	1880
2003	10729	10332	5230	4460	2503	1394	901	1644
2004	10644	8646	6756	3117	2317	1306	727	1329
2005	11272	8638	5907	4250	1863	1385	781	1230
2006	9344	9222	6008	3797	2629	1151	859	1248
2007	7946	7726	6605	4020	2499	1720	752	1365
2008	9687	6525	5454	4244	2326	1428	975	1188
2009	10029	7841	4413	3105	1985	1053	641	960
2010	12485	7983	5060	2370	1237	765	395	603

Table 3.2.8

West of Kintyre: Standard errors of estimates of population abundance by age and year (in thousands) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	1140	873	755	797	878	972	1034	1886
1983	991	909	680	588	599	668	737	1571
1984	935	787	707	529	423	434	485	1284
1985	884	737	602	532	342	281	284	944
1986	897	717	581	467	382	257	212	809
1987	904	737	576	459	348	293	201	732
1988	651	730	576	438	334	258	220	653
1989	629	531	588	456	337	262	205	637
1990	836	512	426	466	360	268	211	616
1991	802	659	405	331	365	286	214	590
1992	839	644	524	320	259	288	228	557
1993	955	680	485	393	240	197	222	510
1994	814	771	470	337	282	175	145	434
1995	980	655	563	324	219	185	116	319
1996	972	812	495	396	220	152	128	248
1997	968	774	575	333	258	147	102	205
1998	891	750	533	392	202	159	92	164
1999	922	702	521	363	202	115	89	127
2000	885	734	486	355	231	143	85	147
2001	676	702	512	315	180	126	83	131
2002	968	551	526	357	175	110	80	135
2003	863	808	407	360	196	105	70	131
2004	862	710	547	232	189	115	65	123
2005	982	711	497	364	152	134	85	135
2006	882	815	510	331	247	108	97	154
2007	959	740	634	392	257	198	88	194
2008	1236	802	564	487	289	198	153	207
2009	1486	1029	615	428	336	207	142	242
2010	1764	1241	842	477	294	232	141	242

Table 3.2.9

West of Kintyre: Estimates of fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	0.100	0.124	0.126	0.208	0.208	0.208	0.208	0.208
1983	0.110	0.151	0.167	0.244	0.244	0.244	0.244	0.244
1984	0.126	0.185	0.226	0.324	0.324	0.324	0.324	0.324
1985	0.099	0.144	0.178	0.248	0.248	0.248	0.248	0.248
1986	0.092	0.130	0.164	0.222	0.222	0.222	0.222	0.222
1987	0.125	0.157	0.199	0.236	0.236	0.236	0.236	0.236
1988	0.107	0.133	0.160	0.184	0.184	0.184	0.184	0.184
1989	0.113	0.138	0.159	0.140	0.140	0.140	0.140	0.140
1990	0.121	0.156	0.178	0.146	0.146	0.146	0.146	0.146
1991	0.085	0.165	0.175	0.156	0.156	0.156	0.156	0.156
1992	0.080	0.211	0.235	0.201	0.201	0.201	0.201	0.201
1993	0.085	0.218	0.259	0.225	0.225	0.225	0.225	0.225
1994	0.075	0.206	0.288	0.326	0.326	0.326	0.326	0.326
1995	0.065	0.154	0.210	0.234	0.234	0.234	0.234	0.234
1996	0.084	0.189	0.208	0.258	0.258	0.258	0.258	0.258
1997	0.090	0.207	0.228	0.277	0.277	0.277	0.277	0.277
1998	0.082	0.220	0.271	0.343	0.343	0.343	0.343	0.343
1999	0.066	0.186	0.244	0.253	0.253	0.253	0.253	0.253
2000	0.069	0.211	0.308	0.409	0.409	0.409	0.409	0.409
2001	0.050	0.170	0.272	0.359	0.359	0.359	0.359	0.359
2002	0.049	0.201	0.312	0.449	0.449	0.449	0.449	0.449
2003	0.066	0.275	0.343	0.498	0.498	0.498	0.498	0.498
2004	0.059	0.228	0.315	0.364	0.364	0.364	0.364	0.364
2005	0.053	0.211	0.284	0.329	0.329	0.329	0.329	0.329
2006	0.040	0.184	0.251	0.274	0.274	0.274	0.274	0.274
2007	0.047	0.195	0.294	0.395	0.395	0.395	0.395	0.395
2008	0.062	0.241	0.413	0.592	0.592	0.592	0.592	0.592
2009	0.079	0.287	0.465	0.747	0.747	0.747	0.747	0.747
2010	0.106	0.352	0.561	0.887	0.887	0.887	0.887	0.887

Table 3.2.10

West of Kintyre: Standard errors of estimates of log fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	0.181	0.183	0.189	0.112	0.112	0.112	0.112	0.112
1983	0.174	0.175	0.177	0.111	0.111	0.111	0.111	0.111
1984	0.172	0.171	0.171	0.111	0.111	0.111	0.111	0.111
1985	0.173	0.174	0.175	0.128	0.128	0.128	0.128	0.128
1986	0.172	0.174	0.175	0.124	0.124	0.124	0.124	0.124
1987	0.169	0.171	0.171	0.120	0.120	0.120	0.120	0.120
1988	0.170	0.171	0.173	0.125	0.125	0.125	0.125	0.125
1989	0.167	0.169	0.170	0.121	0.121	0.121	0.121	0.121
1990	0.166	0.167	0.168	0.115	0.115	0.115	0.115	0.115
1991	0.170	0.166	0.167	0.110	0.110	0.110	0.110	0.110
1992	0.171	0.161	0.163	0.104	0.104	0.104	0.104	0.104
1993	0.169	0.159	0.161	0.104	0.104	0.104	0.104	0.104
1994	0.172	0.164	0.156	0.099	0.099	0.099	0.099	0.099
1995	0.173	0.166	0.163	0.107	0.107	0.107	0.107	0.107
1996	0.170	0.162	0.161	0.104	0.104	0.104	0.104	0.104
1997	0.169	0.161	0.163	0.101	0.101	0.101	0.101	0.101
1998	0.171	0.161	0.158	0.094	0.094	0.094	0.094	0.094
1999	0.173	0.165	0.162	0.112	0.112	0.112	0.112	0.112
2000	0.171	0.164	0.156	0.092	0.092	0.092	0.092	0.092
2001	0.173	0.170	0.162	0.102	0.102	0.102	0.102	0.102
2002	0.174	0.166	0.157	0.097	0.097	0.097	0.097	0.097
2003	0.172	0.158	0.154	0.100	0.100	0.100	0.100	0.100
2004	0.174	0.168	0.162	0.117	0.117	0.117	0.117	0.117
2005	0.176	0.170	0.167	0.119	0.119	0.119	0.119	0.119
2006	0.179	0.176	0.175	0.129	0.129	0.129	0.129	0.129
2007	0.180	0.179	0.175	0.117	0.117	0.117	0.117	0.117
2008	0.187	0.188	0.178	0.117	0.117	0.117	0.117	0.117
2009	0.204	0.210	0.205	0.144	0.144	0.144	0.144	0.144
2010	0.243	0.253	0.254	0.211	0.211	0.211	0.211	0.211

Table 3.2.11

West of Kintyre: Stock summary from the final TSA run.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1982	216	202	1382	11935	0.153
1983	175	179	1049	9526	0.187
1984	226	228	1049	8232	0.245
1985	125	143	844	7597	0.190
1986	101	111	723	7782	0.172
1987	125	119	708	7620	0.197
1988	72	82	593	5557	0.159
1989	66	70	587	6274	0.145
1990	84	83	662	9999	0.160
1991	85	88	716	10909	0.165
1992	108	107	711	11865	0.215
1993	136	131	812	14157	0.234
1994	154	157	837	13338	0.273
1995	121	131	925	14453	0.199
1996	165	152	948	14631	0.218
1997	193	172	987	14025	0.238
1998	214	184	918	12396	0.278
1999	164	147	907	12498	0.228
2000	209	193	886	12215	0.309
2001	151	150	765	9099	0.267
2002	176	166	781	12611	0.321
2003	187	179	726	10729	0.372
2004	142	138	699	10644	0.302
2005	141	135	743	11272	0.275
2006	110	113	670	9344	0.236
2007	135	147	690	7946	0.295
2008	187	182	652	9687	0.415
2009	168	159	553	10029	0.500
2010	178	167	566	12485	0.600

Table 3.3.1

North West: Quarterly dredge landings (UK vessels into Scotland) and sampling levels, 1982-2010.

	Landings (tonnes)					Numbers Aged and Measured/Boats Sampled			
	Qtr1	**Qtr2**	**Qtr3**	**Qtr4**	**Total**	**Qtr1**	**Qtr2**	**Qtr3**	**Qtr4**
1982	834	1280	599	460	3173	3078/11	1407/6	175/1	172/1
1983	334	797	519	385	2035	1899/11	473/3	1490/8	851/6
1984	447	872	519	381	2219	1503/9	605/3	3433/19	1166/5
1985	359	580	339	246	1524	1239/7	844/4	974/5	2240/13
1986	465	326	355	291	1437	569/3	3624/16	1640/9	1251/6
1987	365	547	365	393	1670	2145/11	3774/19	2117/11	285/2
1988	374	493	324	417	1608	179/1	1341/7	244/2	267/2
1989	201	593	396	391	1581	448/2	1089/7	1610/11	593/3
1990	177	467	356	357	1357	0	3081/18	702/3	3727/14
1991	361	195	244	304	1104	3115/11	2631/12	10104/15	4617/16
1992	238	238	262	332	1070	9098/26	7461/13	4637/13	3958/15
1993	158	265	292	261	976	7826/22	3659/14	4911/17	2671/12
1994	428	361	430	626	1845	1855/9	3335/16	3166/13	3386/14
1995	308	154	371	533	1366	3273/14	2133/8	1431/7	6054/28
1996	473	335	694	535	2037	3449/16	2942/12	4790/23	6873/30
1997	311	262	435	1292	2300	2382/10	266/2	1384/7	9011/41
1998	562	605	804	727	2698	1646/11	1367/8	4097/20	4895/27
1999	550	483	50	4	1087	1347/8	360/2	0	0
2000	869	1148	521	799	3337	5022/22	3010/15	2399/11	1100/5
2001	1253	1017	933	929	4132	5378/26	4060/19	2707/13	4730/25
2002	626	1228	1269	1139	4262	3203/15	4536/24	1397/7	2101/12
2003	980	1031	607	822	3440	2589/12	2161/12	1785/7	3410/16
2004	859	802	735	767	3163	762/3	1138/6	1471/6	615/4
2005	729	947	402	439	2517	0	195/9	0	977/6
2006	250	368	256	261	1135	494/3	1428/7	204/1	295/2
2007	454	218	205	422	1299	654/2	278/2	0	1157/5
2008	1078	419	358	347	2202	250/1	851/4	252/1	1566/7
2009	252	437	332	297	1318	0	2125/9	759/3	715/3
2010	252	303	246	334	1135	263/1	2161/15	485/3	2233/12

Table 3.3.2

North West: Total catch-at-age numbers (in thousands).

	2	3	4	5	6	7	8	9	10+
1982	432	1561	2029	2707	2746	2554	2215	1154	2641
1983	34	334	514	1000	2024	2247	2395	1659	2870
1984	399	1392	1760	1640	1903	1760	1721	955	2514
1985	192	724	1302	1113	1124	1261	1142	897	2139
1986	116	567	984	991	1290	1142	1333	1111	2299
1987	51	725	1107	1206	1518	1087	1571	1265	4038
1988	22	415	988	1230	1128	980	1318	1061	3317
1989	15	243	891	1401	1418	1451	1173	950	2444
1990	203	1143	791	669	859	945	833	650	2126
1991	129	822	1597	1013	1042	883	628	360	1061
1992	94	879	1258	1505	932	535	584	424	1221
1993	198	803	1726	1284	1054	486	363	257	537
1994	8	667	2371	3332	1709	892	565	257	1273
1995	28	528	1430	2234	2319	1174	786	328	1218
1996	4	538	1976	2705	2675	1656	1167	553	1714
1997	73	1242	2408	2771	2676	2453	1665	1010	1173
1998	185	1178	2822	2852	2738	1981	2173	1249	2008
1999	16	589	1523	1288	1020	889	663	299	464
2000	25	1557	3511	3456	2980	2562	2038	1279	1475
2001	6	1089	5099	4696	3884	2800	2505	1613	2924
2002	6	1353	6210	6936	3689	2672	1786	909	1855
2003	15	754	3259	5299	4301	2949	1809	1163	1651
2004	9	696	3092	4555	4073	2312	1399	871	1500
2005	8	662	2417	3168	3373	2119	963	586	1240
2006	0	59	448	1111	1881	1548	1137	551	719
2007	0	121	1446	1756	1485	1823	1039	712	966
2008	0	364	1969	4261	3518	1609	588	205	160
2009	9	483	925	1401	1573	1570	1138	696	436
2010	0	150	1139	1444	1193	1197	896	488	545

Table 3.3.3

North West: Mean weights-at-age (muscle) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1982	0.015	0.019	0.022	0.027	0.029	0.031	0.034	0.036	0.040
1983	0.016	0.018	0.021	0.023	0.024	0.027	0.028	0.031	0.034
1984	0.019	0.021	0.024	0.026	0.028	0.030	0.030	0.032	0.039
1985	0.017	0.020	0.023	0.026	0.029	0.030	0.030	0.033	0.036
1986	0.016	0.019	0.022	0.023	0.025	0.027	0.029	0.031	0.033
1987	0.016	0.018	0.021	0.023	0.024	0.026	0.026	0.027	0.030
1988	0.019	0.021	0.023	0.025	0.026	0.027	0.029	0.029	0.031
1989	0.019	0.020	0.023	0.024	0.025	0.027	0.028	0.029	0.032
1990	0.017	0.021	0.024	0.027	0.025	0.027	0.027	0.029	0.033
1991	0.017	0.019	0.022	0.025	0.027	0.030	0.031	0.033	0.033
1992	0.019	0.020	0.023	0.025	0.027	0.029	0.029	0.030	0.032
1993	0.020	0.021	0.024	0.026	0.028	0.030	0.032	0.033	0.035
1994	0.019	0.020	0.023	0.027	0.030	0.032	0.033	0.035	0.037
1995	0.020	0.022	0.023	0.025	0.028	0.031	0.032	0.034	0.037
1996	0.017	0.020	0.023	0.026	0.028	0.030	0.031	0.031	0.032
1997	0.019	0.021	0.022	0.025	0.028	0.031	0.032	0.034	0.037
1998	0.020	0.021	0.023	0.026	0.029	0.030	0.030	0.031	0.034
1999	0.017	0.020	0.024	0.028	0.031	0.033	0.034	0.035	0.039
2000	0.018	0.022	0.024	0.027	0.030	0.031	0.033	0.034	0.035
2001	0.017	0.020	0.023	0.025	0.028	0.030	0.031	0.032	0.034
2002	0.016	0.020	0.023	0.026	0.029	0.032	0.034	0.035	0.037
2003	0.017	0.020	0.022	0.025	0.028	0.031	0.033	0.034	0.036
2004	0.016	0.019	0.022	0.026	0.028	0.031	0.032	0.034	0.035
2005	0.016	0.020	0.023	0.027	0.029	0.031	0.034	0.036	0.035
2006	0.017	0.020	0.022	0.024	0.027	0.029	0.031	0.033	0.036
2007	0.016	0.016	0.020	0.024	0.024	0.027	0.030	0.030	0.029
2008	0.016	0.021	0.024	0.028	0.031	0.034	0.038	0.042	0.041
2009	0.021	0.021	0.023	0.027	0.029	0.031	0.033	0.035	0.039
2010	0.018	0.020	0.023	0.027	0.030	0.032	0.035	0.039	0.045

Table 3.3.4

North West: Available research-vessel survey data by age and year (numbers $hour^{-1} metre^{-1}$).

	2	3	4	5	6	7	8	9	10+
1993	0.12	6.42	12.51	9.20	5.89	3.67	2.53	3.07	8.84
1994	0.05	3.69	9.16	11.07	7.55	4.36	2.77	2.17	9.94
1995	0.13	5.24	7.70	10.37	8.02	4.30	2.85	2.30	5.61
1996	0.13	3.47	7.67	7.65	8.09	6.20	2.82	1.61	6.53
1997	0.07	2.84	9.43	8.75	6.46	5.74	3.60	2.13	5.09
1998	0.22	7.53	8.34	8.50	5.84	4.95	4.19	3.01	5.26
1999	0.12	4.60	9.63	6.22	5.23	4.16	3.83	3.09	4.49
2000	0.08	9.72	11.32	9.14	4.65	4.72	3.47	3.20	4.51
2001	0.37	6.22	14.29	8.26	5.01	2.94	2.70	1.59	2.88
2002	0.02	6.29	9.69	13.82	5.76	3.44	2.64	2.02	2.76
2003	0.90	7.89	10.48	9.35	7.93	3.76	2.26	1.87	4.22
2004	0.61	4.82	7.88	8.62	7.58	5.45	2.85	2.13	4.14
2005	0.02	2.27	5.05	6.38	7.24	6.02	4.80	3.68	5.77
2006	0.02	2.44	6.43	6.42	6.51	5.59	4.39	3.35	4.82
2007	0.01	0.86	3.80	4.05	4.66	4.38	3.67	2.93	4.40
2008	0.02	0.29	1.33	3.69	4.37	4.38	3.45	2.68	7.96
2009	0.03	0.78	2.73	3.89	4.43	3.58	3.12	1.57	7.94
2010	0.01	1.36	3.59	3.44	3.28	2.86	2.04	0.84	7.55

Table 3.3.5

North West: Final TSA run parameter estimates.

Parameter	Notation	Description	2011
Initial fishing mortality	F(3, 1982)	Fishing mortality at age a in year y	0.06
	F(4, 1982)		0.12
	F(6, 1982)		0.41
Survey selectivities	Φ(3)	Survey selectivity at age a	0.22
	Φ(4)		0.43
	Φ(5)		0.57
	Φ(6)		0.65
	Φ(7)		0.71
	Φ(8)		0.79
	Φ(9)		0.97
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0.00
	σ_U	Persistent changes in selection (age effect in F)	0.07
	σ_V	Transitory changes in the year effect in F	0.25
	σ_Y	Persistent changes in the year effect in F	0.08
Survey catchability standard deviations	σ_Ω	Transitory changes in survey catchability	0.04
	σ_β	Persistent changes in survey catchability	0.09
Measurement coefficients of variation	cv landings	Coefficient of variation of landings-at-age data	0.27
	cv survey	Coefficient of variation of survey data	0.22
Recruitment	η^2	Mean	2.75
	cv rec	Coefficient of variation of recruitment curve	0.32

Table 3.3.6

North West: Estimated population abundance by age and year (in thousands) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	25773	24132	21787	16933	14438	12324	7194	15533
1983	22764	21149	19063	16619	11629	10070	8620	15687
1984	20825	18814	16986	15012	12542	8772	7602	18348
1985	17599	16987	14704	12950	10805	9028	6315	18681
1986	16670	14541	13530	11488	9660	8059	6730	18629
1987	16231	13776	11548	10483	8439	7109	5922	18620
1988	12176	13298	10723	8664	7243	5862	4917	16936
1989	13955	10014	10417	8069	6045	5030	4066	15079
1990	19259	11475	7702	7669	5460	4062	3373	12838
1991	23120	15873	9046	5792	5411	3814	2809	11182
1992	32073	19192	12342	6837	4129	3863	2704	9838
1993	32862	26784	15253	9233	5016	3002	2806	9013
1994	28782	27609	21558	11849	6939	3800	2267	8893
1995	29783	24007	21729	16104	8577	4993	2749	8028
1996	30171	25001	19123	16559	11805	6288	3648	7876
1997	29861	25197	19567	14183	11651	8288	4415	8071
1998	34775	24794	19219	14010	9458	7756	5512	8302
1999	37694	28869	18674	13536	9074	6125	5019	8939
2000	49776	31884	23326	14588	10180	6824	4607	10499
2001	41878	41483	23925	16299	9223	6453	4327	9578
2002	37230	34510	29957	15580	9248	5181	3655	7852
2003	32572	30870	25075	19717	9138	5424	3031	6737
2004	27286	27140	22965	16901	12113	5566	3307	5951
2005	26563	22828	20628	15966	10970	7863	3603	5997
2006	25644	22299	17673	14783	10906	7493	5371	6558
2007	19127	21701	17885	13447	10914	8054	5533	8809
2008	17487	16162	17255	13405	9867	8022	5920	10542
2009	20874	14695	12532	12320	9569	7045	5728	11755
2010	18031	17619	11664	9311	9143	7101	5228	12975

Table 3.3.7

North West: Standard errors of estimates of population abundance by age and year (in thousands) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	282	239	217	150	121	110	84	144
1983	261	233	190	161	99	86	77	136
1984	278	217	192	155	132	86	76	177
1985	248	230	175	151	120	104	70	200
1986	235	206	187	141	119	96	85	214
1987	203	195	168	152	112	95	78	231
1988	139	167	158	135	116	87	75	233
1989	130	116	137	127	104	91	69	231
1990	191	109	95	110	98	81	71	220
1991	182	160	89	77	86	77	65	209
1992	224	153	132	72	60	67	61	194
1993	208	189	126	106	57	47	53	177
1994	173	175	156	102	83	45	37	156
1995	187	145	141	121	78	64	35	129
1996	182	157	118	112	93	60	49	110
1997	183	152	126	91	83	70	45	98
1998	230	153	121	94	64	60	51	88
1999	226	193	119	89	64	45	43	86
2000	297	192	159	95	69	50	36	91
2001	257	249	148	116	61	45	33	78
2002	260	213	190	104	64	35	27	61
2003	260	217	160	135	60	39	22	52
2004	235	220	171	120	90	42	27	50
2005	235	200	178	132	89	68	32	56
2006	244	200	164	143	106	73	56	70
2007	217	208	167	135	117	88	61	102
2008	244	184	173	137	111	97	73	133
2009	350	207	152	144	115	93	81	169
2010	517	297	173	127	122	98	79	206

Table 3.3.8

North West: Estimates of fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	0.050	0.084	0.109	0.156	0.156	0.156	0.156	0.156
1983	0.040	0.069	0.089	0.131	0.131	0.131	0.131	0.131
1984	0.054	0.096	0.121	0.179	0.179	0.179	0.179	0.179
1985	0.041	0.076	0.097	0.144	0.144	0.144	0.144	0.144
1986	0.041	0.078	0.102	0.157	0.157	0.157	0.157	0.157
1987	0.049	0.098	0.132	0.210	0.210	0.210	0.210	0.210
1988	0.044	0.091	0.127	0.198	0.198	0.198	0.198	0.198
1989	0.045	0.099	0.140	0.214	0.214	0.214	0.214	0.214
1990	0.039	0.087	0.124	0.179	0.179	0.179	0.179	0.179
1991	0.035	0.085	0.124	0.165	0.165	0.165	0.165	0.165
1992	0.030	0.078	0.117	0.149	0.149	0.149	0.149	0.149
1993	0.024	0.067	0.102	0.125	0.125	0.125	0.125	0.125
1994	0.030	0.090	0.141	0.172	0.172	0.172	0.172	0.172
1995	0.025	0.077	0.122	0.160	0.160	0.160	0.160	0.160
1996	0.029	0.095	0.148	0.202	0.202	0.202	0.202	0.202
1997	0.036	0.121	0.184	0.257	0.257	0.257	0.257	0.257
1998	0.037	0.134	0.201	0.285	0.285	0.285	0.285	0.285
1999	0.017	0.064	0.096	0.135	0.135	0.135	0.135	0.135
2000	0.033	0.134	0.208	0.302	0.302	0.302	0.302	0.302
2001	0.041	0.175	0.276	0.412	0.412	0.412	0.412	0.412
2002	0.037	0.166	0.267	0.368	0.368	0.368	0.368	0.368
2003	0.033	0.145	0.242	0.337	0.337	0.337	0.337	0.337
2004	0.028	0.125	0.213	0.280	0.280	0.280	0.280	0.280
2005	0.024	0.105	0.183	0.231	0.231	0.231	0.231	0.231
2006	0.016	0.069	0.123	0.153	0.153	0.153	0.153	0.153
2007	0.018	0.076	0.137	0.158	0.158	0.158	0.158	0.158
2008	0.024	0.101	0.185	0.187	0.187	0.187	0.187	0.187
2009	0.019	0.080	0.146	0.148	0.148	0.148	0.148	0.148
2010	0.017	0.072	0.131	0.131	0.131	0.131	0.131	0.131

Table 3.3.9

North West: Standard errors of estimates of log fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	0.155	0.159	0.162	0.152	0.152	0.152	0.152	0.152
1983	0.155	0.161	0.166	0.169	0.169	0.169	0.169	0.169
1984	0.143	0.145	0.147	0.128	0.128	0.128	0.128	0.128
1985	0.142	0.144	0.146	0.128	0.128	0.128	0.128	0.128
1986	0.140	0.142	0.144	0.123	0.123	0.123	0.123	0.123
1987	0.138	0.139	0.140	0.115	0.115	0.115	0.115	0.115
1988	0.137	0.138	0.139	0.112	0.112	0.112	0.112	0.112
1989	0.136	0.136	0.136	0.108	0.108	0.108	0.108	0.108
1990	0.136	0.136	0.136	0.107	0.107	0.107	0.107	0.107
1991	0.136	0.135	0.135	0.105	0.105	0.105	0.105	0.105
1992	0.137	0.135	0.135	0.104	0.104	0.104	0.104	0.104
1993	0.137	0.136	0.135	0.104	0.104	0.104	0.104	0.104
1994	0.137	0.135	0.134	0.103	0.103	0.103	0.103	0.103
1995	0.138	0.136	0.134	0.104	0.104	0.104	0.104	0.104
1996	0.137	0.135	0.132	0.101	0.101	0.101	0.101	0.101
1997	0.136	0.133	0.130	0.098	0.098	0.098	0.098	0.098
1998	0.136	0.132	0.130	0.097	0.097	0.097	0.097	0.097
1999	0.141	0.139	0.137	0.106	0.106	0.106	0.106	0.106
2000	0.138	0.133	0.130	0.095	0.095	0.095	0.095	0.095
2001	0.135	0.130	0.126	0.088	0.088	0.088	0.088	0.088
2002	0.137	0.133	0.129	0.095	0.095	0.095	0.095	0.095
2003	0.141	0.140	0.136	0.106	0.106	0.106	0.106	0.106
2004	0.145	0.147	0.144	0.119	0.119	0.119	0.119	0.119
2005	0.150	0.157	0.154	0.132	0.132	0.132	0.132	0.132
2006	0.154	0.165	0.163	0.139	0.139	0.139	0.139	0.139
2007	0.158	0.173	0.171	0.146	0.146	0.146	0.146	0.146
2008	0.166	0.183	0.181	0.155	0.155	0.155	0.155	0.155
2009	0.180	0.201	0.199	0.167	0.167	0.167	0.167	0.167
2010	0.201	0.219	0.217	0.176	0.176	0.176	0.176	0.176

Table 3.3.10

North West: Stock summary from the final TSA run.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1982	529	419	3847	25773	0.116
1983	365	283	3088	22764	0.096
1984	400	414	3349	20825	0.132
1985	285	304	2976	17599	0.106
1986	267	279	2553	16670	0.112
1987	325	311	2221	16231	0.147
1988	290	275	2088	12176	0.139
1989	272	260	1866	13955	0.151
1990	220	207	1858	19259	0.130
1991	197	193	1913	23120	0.125
1992	194	185	2204	32073	0.115
1993	175	190	2643	32862	0.098
1994	312	301	2904	28782	0.134
1995	283	285	3018	29783	0.120
1996	359	363	3054	30171	0.148
1997	430	466	3143	29861	0.187
1998	475	493	3176	34775	0.206
1999	196	266	3421	37694	0.098
2000	543	598	3993	49776	0.215
2001	678	749	3787	41878	0.288
2002	704	694	3660	37230	0.267
2003	590	593	3317	32572	0.241
2004	512	492	3060	27286	0.206
2005	415	418	3023	26563	0.173
2006	213	264	2789	25644	0.115
2007	238	260	2450	19127	0.124
2008	375	394	2975	17487	0.158
2009	242	273	2660	20874	0.125
2010	217	251	2689	18031	0.111

Table 3.4.1

Clyde: Quarterly dredge landings (UK vessels into Scotland) and market sample details 1985-2010.

	Landings (tonnes)					Numbers Aged and Measured/Boats Sampled			
	Qtr1	**Qtr2**	**Qtr3**	**Qtr4**	**Total**	**Qtr1**	**Qtr2**	**Qtr3**	**Qtr4**
1985	80	24	27	48	180	0	0	0	154/1
1986	24	28	11	12	76	0	0	0	0
1987	25	22	5	40	92	0	0	0	0
1988	57	8	5	9	79	0	0	0	0
1989	21	4	0	6	31	0	0	0	221/1
1990	6	12	0	0	18	0	0	0	0
1991	6	11	11	20	49	0	0	0	396/2
1992	8	5	4	7	23	0	0	0	245/1
1993	21	2	0	51	75	231/1	406/2	0	394/2
1994	86	9	38	49	182	0	0	279/2	324/1
1995	51	56	8	23	139	189/1	330/2	0	0
1996	25	16	27	43	110	220/1	0	234/1	525/2
1997	56	41	18	116	231	0	594/3	0	2024/9
1998	52	48	56	87	243	390/2	147/1	0	244/1
1999	67	36	33	66	201	280/1	0	0	377/2
2000	19	43	103	187	352	257/1	364/2	0	0
2001	78	75	25	126	304	0	0	230/1	913/5
2002	115	83	97	178	473	128/1	303/2	125/1	327/2
2003	99	69	148	192	508	0	296/2	645/4	200/1
2004	140	87	109	205	541	509/2	136/1	0	1721/9
2005	120	63	50	181	414	151/1	221/1	0	815/5
2006	164	48	60	115	387	261/2	0	0	0
2007	79	56	36	128	299	238/2	0	0	112/1
2008	107	120	119	93	439	295/2	0	0	948/5
2009	103	112	112	124	451	170/1	0	0	301/2
2010	101	95	165	167	528	800/3	930/4	852/4	0

Table 3.5.1

Irish Sea: Quarterly dredge landings (UK vessels into Scotland) and market sample details 1985-2010.

	Landings (tonnes)					Numbers Aged and Measured/Boats Sampled			
	Qtr1	**Qtr2**	**Qtr3**	**Qtr4**	**Total**	**Qtr1**	**Qtr2**	**Qtr3**	**Qtr4**
1985	251	196	19	72	538	0	0	0	0
1986	135	82	1	52	270	0	120/1	0	431/3
1987	160	192	0	63	415	0	232/2	238/1	315/2
1988	194	254	0	146	594	0	1348/6	0	0
1989	97	155	0	198	450	0	0	0	0
1990	86	312	1	52	451	0	620/3	0	0
1991	171	78	0	126	374	0	0	628/3	277/1
1992	152	6	0	76	234	650/2	0	286/1	325/1
1993	134	118	0	62	314	1988/7	817/3	1613/7	260/1
1994	81	16	0	146	242	817/3		551/2	326/1
1995	136	107	0	167	410	1206/5	1140/4		1190/5
1996	251	94	0	260	605	231/1	452/2	676/3	525/2
1997	219	62	0	115	397	1110/5	919/4	0	0
1998	215	67	8	392	682	941/4	270/1	0	1652/8
1999	518	145	10	366	1039	1045/5	432/2	206/2	0
2000	191	70	0	197	458	1257/7	0	390/2	339/2
2001	202	149	1	381	732	0	122/1	0	1180/5
2002	221	158	2	256	637	0	0	330/2	0
2003	236	122	0	276	634	0	441/2	702/3	211/1
2004	190	11	0	549	751	0	0	0	1273/7
2005	309	159	0	371	839	142/1	0	0	194/1
2006	308	73	0	351	733	0	285/2	0	701/4
2007	413	44	0	375	831	0	422/2	0	422/2
2008	179	281	1	433	894	227/1	0	0	389/1
2009	451	215	0	784	1450	0	0	0	1923/7
2010	707	266	0	487	1461	947/5	0	0	0

Table 3.6.1

North East: Quarterly dredge landings (UK vessels into Scotland) and market sample details 1984-2010.

	Landings (tonnes)					Numbers Aged and Measured/Boats Sampled			
	Qtr1	Qtr2	Qtr3	Qtr4	Total	Qtr1	Qtr2	Qtr3	Qtr4
1984	91	110	131	71	403	0	0	0	144/1
1985	83	79	155	71	388	0	158/1	0	0
1986	55	198	138	168	559	623/4	906/6	1119/7	0
1987	119	187	259	114	679	485	364/2	0	0
1988	51	163	312	145	671	0	0	305/2	0
1989	87	352	352	103	894	0	298/2	706/4	176/1
1990	66	480	266	140	952	0	324/2	1089/5	789/5
1991	91	111	97	86	385	1305/7	162/1	1056/5	2450/10
1992	106	932	509	186	1733	594/3	2749/12	2467/9	2576/12
1993	214	562	427	368	1571	997/4	2103/9	2657/13	1677/8
1994	184	879	881	378	2322	418/2	4490/17	4768/20	928/4
1995	458	1265	300	1127	3150	855/4	1553/7	379/2	3255/13
1996	833	1403	658	597	3491	1624/8	2067/8	2411/11	2228/10
1997	572	851	1044	477	2944	2592/9	1619/7	2165/10	788/4
1998	394	571	514	259	1738	713/4	1369/7	618/4	827/5
1999	211	346	869	256	1682	203/1	1109/7	3031/15	1104/6
2000	335	548	350	278	1511	1056/6	1469/10	1321/8	2100/12
2001	606	544	456	130	1736	1211/8	1403/8	1291/7	556/3
2002	146	163	275	153	737	185/1	542/3	1315/6	0
2003	177	346	930	361	1814	352/2	1020/5	1013/5	580/3
2004	438	444	702	374	1958	326/2	176/1	1539/6	377/2
2005	224	365	1038	399	2026	359/2	138/1	378/2	347/2
2006	270	591	773	162	1796	165/1	388/2	967/6	0
2007	92	436	584	221	1333	0	0	784/3	164/1
2008	100	358	736	191	1385	838/4	1561/7	1397/6	643/4
2009	129	939	936	151	2155	471/2	944/4	159/1	0
2010	63	590	515	99	1267	0	441/2	702/3	211/1

Table 3.6.2

North East: Total catch-at-age numbers (in thousands).

	2	3	4	5	6	7	8	9	10+
1984	0	27	68	82	187	384	471	361	393
1985	3	29	32	90	140	333	411	376	521
1986	5	97	145	80	161	427	488	433	1099
1987	0	100	274	214	212	428	515	310	796
1988	0	104	659	541	190	181	348	330	1838
1989	0	39	218	464	618	759	697	542	1108
1990	244	316	337	553	660	601	613	526	1094
1991	134	338	389	195	130	140	144	154	481
1992	15	272	2703	2018	880	487	593	441	2798
1993	17	232	2710	2271	1097	570	346	181	1216
1994	14	375	2686	6766	3243	1249	486	180	1195
1995	10	470	3210	7334	5677	1869	700	389	959
1996	9	166	1134	3800	5910	4336	1826	567	948
1997	3	130	1143	3091	4781	4117	1919	475	511
1998	0	203	299	616	1186	2063	1489	1106	1080
1999	4	213	512	795	1353	1898	2102	1183	1127
2000	1	528	1669	793	658	896	1297	1375	1565
2001	3	102	1283	1017	531	423	899	744	1821
2002	0	200	1533	888	669	340	271	200	328
2003	0	24	1051	3319	2926	1908	1076	497	1269
2004	1	208	1594	2411	2048	1326	767	403	930
2005	9	299	861	1391	1459	2484	1188	702	1781
2006	0	559	570	1173	1288	1533	935	645	1528
2007	1	282	2120	1722	1008	1019	616	250	336
2008	6	481	1150	2364	1358	1011	599	277	360
2009	31	203	1632	3843	2422	999	873	750	573
2010	0	203	1281	1553	1629	1169	622	361	354

Table 3.6.3

North East: Mean weights-at-age (muscle) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1984	0.012	0.012	0.017	0.018	0.020	0.021	0.024	0.023	0.025
1985	0.011	0.013	0.016	0.016	0.018	0.020	0.022	0.023	0.025
1986	0.013	0.015	0.018	0.021	0.023	0.024	0.025	0.026	0.028
1987	0.012	0.016	0.017	0.020	0.023	0.025	0.028	0.028	0.029
1988	0.012	0.012	0.016	0.019	0.019	0.020	0.019	0.022	0.022
1989	0.012	0.013	0.017	0.018	0.019	0.022	0.024	0.025	0.027
1990	0.015	0.018	0.018	0.020	0.022	0.023	0.024	0.026	0.029
1991	0.015	0.016	0.017	0.021	0.024	0.025	0.026	0.028	0.030
1992	0.014	0.014	0.015	0.018	0.020	0.022	0.024	0.026	0.027
1993	0.013	0.014	0.016	0.020	0.023	0.025	0.026	0.028	0.031
1994	0.014	0.015	0.015	0.017	0.020	0.022	0.023	0.025	0.027
1995	0.012	0.014	0.016	0.018	0.020	0.023	0.024	0.025	0.028
1996	0.014	0.016	0.017	0.018	0.020	0.023	0.025	0.028	0.030
1997	0.013	0.014	0.016	0.017	0.019	0.020	0.022	0.024	0.026
1998	0.013	0.017	0.017	0.019	0.020	0.022	0.024	0.025	0.027
1999	0.011	0.014	0.017	0.019	0.020	0.022	0.023	0.025	0.028
2000	0.013	0.016	0.018	0.022	0.023	0.025	0.026	0.028	0.031
2001	0.011	0.014	0.017	0.019	0.021	0.023	0.024	0.026	0.029
2002	0.012	0.015	0.016	0.019	0.023	0.025	0.025	0.027	0.029
2003	0.012	0.013	0.016	0.018	0.019	0.021	0.022	0.025	0.026
2004	0.015	0.015	0.017	0.020	0.021	0.023	0.024	0.024	0.027
2005	0.010	0.014	0.016	0.021	0.024	0.024	0.026	0.026	0.031
2006	0.012	0.016	0.016	0.019	0.021	0.023	0.025	0.026	0.030
2007	0.013	0.015	0.017	0.019	0.021	0.025	0.028	0.030	0.034
2008	0.018	0.020	0.018	0.018	0.022	0.026	0.028	0.031	0.035
2009	0.015	0.016	0.018	0.020	0.023	0.025	0.027	0.027	0.030
2010	0.015	0.017	0.018	0.018	0.020	0.022	0.025	0.027	0.030

Table 3.6.4

Summary of Marine Scotland Science North Sea scallop dredge surveys 1993-2010. Data from greyed out surveys are not used in the assessment.

Vessel	Cruise dates		Dredge Type	No. of dredges	Width (m)	No. of hauls		No. of scallops
	From	To				NE	EC	
R.V. Clupea	17-May-93	25-May-93	A	3	4.5	30		1565
			B	3				
M.F.V. Aspire	01-Aug-94	26-Aug-94	C	6	7.35	66	49	23749
			B	5				
M.F.V. Argo	07-Aug-95	01-Sep-95	A	6	9	74	48	14677
			B	6				
M.F.V. Aspire	18-Sep-95	20-Sep-95	C	6	7.35	20		3990
			B	5				
M.F.V. Argo	12-Aug-96	06-Sep-96	A	6	9	77	46	15566
			B	6				
M.F.V. Star of Annan	07-Oct-96	10-Oct-96	A	8	12	20		3466
			B	8				
R.V. Clupea	11-Nov-97	01-Dec-97	A	3	4.5	58	0	3750
			B	3				
R.V. Clupea	21-Jan-99	09-Feb-99	A	3	4.5	71	38	5035
			B	3				
R.V. Clupea	23-Sep-99	30-Sep-99	A	3	4.5	77	39	4908
			B	3				
R.V. Clupea	25-Sep-00	13-Oct-00	A	3	4.5	65	36	4043
			B	3				
R.V. Clupea	15-Jun-01	02-Jul-01	A	3	4.5	75	45	4674
			B	3				
R.V. Clupea	15-Jul-02	02-Aug-02	A	3	4.5	96	45	6980
			B	3				
R.V. Clupea	02-Jul-03	21-Jul-03	A	3	4.5	87	46	7965
			B	3				
R.V. Clupea	23-Jun-04	12-Jul-04	A	3	4.5	71	40	5214
			B	3				
R.V. Clupea	17-Jun-05	11-Jul-05	A	3	4.5	88	44	6681
			B	3				
R.V. Clupea	23-May-06	12-Jun-06	A	3	4.5	84	44	8736
			B	3				
R.V. Clupea	18-Jun-07	08-Jul-07	A	3	4.5	77	46	6548
			B	3				
R.V. Alba na Mara	27-Jun-08	16-Jul-08	A	6	9	62	32	13110
			B	6				
R.V. Alba na Mara	01-Jul-09	20-Jul-09	A	6	9	56	43	11932
			B	6				
R.V. Alba na Mara	25-Jun-10	14-Jul-10	A	6	9	69	45	13913
			B	6				

Dredge Type A: Standard commercial dredge. 2.5’ wide. 9 tooth bar. Large belly rings.

Dredge Type B: Laboratory sampling dredge. 2.5’ wide. 11 tooth bar. Small belly rings.

Dredge Type C: Small commercial dredge. 2’ wide. 7 tooth bar. Large belly rings.

Table 3.6.5

North East: Available research-vessel survey data by age and year (numbers $hour^{-1}metre^{-1}$).

	2	3	4	5	6	7	8	9	10+
1994	0.09	1.18	12.38	16.74	8.60	3.62	1.71	1.10	6.85
1995	0.02	2.10	5.98	13.82	10.33	4.02	1.41	0.63	2.95
1996	0.00	0.22	4.47	7.12	11.53	7.90	2.20	0.68	2.30
1997	0.11	1.00	2.33	3.75	6.00	7.41	4.34	1.31	2.46
1998	0.12	1.28	1.32	1.77	1.59	3.18	4.39	4.14	3.63
1999	0.08	2.41	2.61	1.56	1.30	2.93	3.48	3.44	3.36
2000	0.10	2.77	4.93	2.18	1.21	1.85	2.52	2.77	2.41
2001	0.02	1.67	4.03	3.85	1.05	1.66	2.17	2.12	2.58
2002	0.04	4.40	7.12	4.97	2.22	1.51	1.87	2.16	2.16
2003	0.11	1.06	5.83	8.32	2.85	3.56	1.36	0.81	4.43
2004	0.47	1.62	2.64	5.23	4.05	2.12	1.05	1.10	2.46
2005	0.16	2.50	2.77	2.91	4.66	4.04	2.09	1.42	1.76
2006	0.01	3.34	5.00	4.50	3.53	4.46	3.09	2.65	3.51
2007	0.04	0.93	4.20	4.31	3.17	2.74	2.30	1.81	2.58
2008	0.05	1.43	5.39	7.58	4.52	3.50	2.64	1.28	3.94
2009	0.00	0.62	2.42	4.13	5.43	3.27	2.02	0.88	4.77
2010	0.01	1.79	3.50	5.57	4.98	4.32	2.62	0.87	4.65

Table 3.6.6

North East: Final TSA run parameter estimates.

Parameter	Notation	Description	2011
Initial fishing mortality	F(3, 1982)	Fishing mortality at age a in year y	0.004
	F(4, 1982)		0.03
	F(6, 1982)		0.05
Survey selectivities	Φ(3)	Survey selectivity at age a	0.01
	Φ(4)		0.03
	Φ(5)		0.05
	Φ(6)		0.05
	Φ(7)		0.07
	Φ(8)		0.09
	Φ(9)		0.10
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0.00
	σ_U	Persistent changes in selection (age effect in F)	0.06
	σ_V	Transitory changes in the year effect in F	0.24
	σ_Y	Persistent changes in the year effect in F	0.26
Survey catchability standard deviations	σ_Ω	Transitory changes in survey catchability	0.15
	σ_β	Persistent changes in survey catchability	0.0
Measurement coefficients of variation	cv landings	Coefficient of variation of landings-at-age data	0.56
	cv survey	Coefficient of variation of survey data	0.32
Recruitment	η^2	Mean	19.52
	cv rec	Coefficient of variation of recruitment curve	0.63

Table 3.6.7

North East: Estimated population abundance by age and year (in thousands) from the final TSA run.

	3	4	5	6	7	8	9	10+
1984	8794	5384	4736	5640	7982	9571	7184	7217
1985	8943	7549	4549	3972	4612	6533	7834	11790
1986	9600	7672	6398	3826	3223	3745	5306	15939
1987	10550	8219	6422	5314	2963	2499	2906	16480
1988	6966	9019	6797	5263	4040	2259	1907	14785
1989	7910	5941	7356	5415	3866	2957	1663	12298
1990	14207	6720	4718	5516	3551	2642	2039	9660
1991	28094	12018	5371	3498	3482	2302	1774	7957
1992	47048	23965	9735	4305	2489	2451	1653	7160
1993	43852	39644	18541	6809	2661	1544	1536	5491
1994	26980	37174	31442	13956	4759	1802	1049	4785
1995	17956	22765	28417	22084	8144	2746	1067	3445
1996	10721	15084	16919	19184	12359	4610	1554	2532
1997	7749	9015	11448	11757	11442	7349	2767	2418
1998	8985	6553	6927	8167	7393	7174	4562	3194
1999	15444	7643	5143	5114	5450	4951	4813	5191
2000	18973	13116	6075	3770	3401	3650	3311	6672
2001	23493	16121	10403	4481	2474	2241	2425	6613
2002	22245	19906	12811	7799	3063	1694	1537	6205
2003	14118	18946	16051	9852	5615	2209	1220	5574
2004	14479	11884	14195	10844	5699	3254	1277	3928
2005	17965	12231	9114	10037	6727	3518	2013	3216
2006	24360	15139	9258	6270	5984	3998	2082	3100
2007	19416	20558	11604	6501	3851	3656	2447	3172
2008	16715	16445	16098	8446	4270	2529	2400	3689
2009	13544	14151	12868	11675	5539	2797	1658	3989
2010	14914	11398	10716	8805	7038	3339	1687	3405

Table 3.6.8

North East: Standard errors of estimates of population abundance by age and year (in thousands) from the final TSA run.

	3	4	5	6	7	8	9	10+
1984	1.370	0.835	0.654	0.811	1.090	1.151	1.412	2.440
1985	2.194	1.176	0.703	0.547	0.670	0.907	0.957	2.351
1986	3.554	1.883	0.999	0.595	0.451	0.554	0.752	2.193
1987	3.536	3.043	1.590	0.841	0.469	0.360	0.444	2.021
1988	1.281	3.026	2.572	1.338	0.647	0.367	0.286	1.791
1989	1.191	1.094	2.531	2.126	0.986	0.480	0.279	1.535
1990	3.061	1.018	0.918	2.116	1.577	0.753	0.379	1.367
1991	4.161	2.618	0.852	0.757	1.529	1.157	0.562	1.234
1992	4.155	3.563	2.210	0.713	0.573	1.187	0.902	1.242
1993	3.502	3.507	2.823	1.688	0.431	0.347	0.737	1.155
1994	2.277	2.974	2.839	2.245	1.073	0.292	0.236	1.055
1995	2.012	1.928	2.430	2.201	1.375	0.657	0.192	0.746
1996	0.972	1.695	1.483	1.760	1.249	0.742	0.355	0.474
1997	0.880	0.818	1.276	1.070	1.039	0.736	0.414	0.377
1998	1.184	0.742	0.634	0.886	0.626	0.636	0.445	0.387
1999	1.946	1.002	0.569	0.463	0.535	0.419	0.438	0.515
2000	2.178	1.646	0.762	0.401	0.283	0.336	0.286	0.613
2001	2.230	1.841	1.253	0.524	0.235	0.186	0.223	0.600
2002	2.730	1.889	1.443	0.923	0.338	0.165	0.140	0.593
2003	1.304	2.333	1.557	1.138	0.683	0.254	0.130	0.571
2004	1.649	1.101	1.789	1.133	0.654	0.411	0.159	0.452
2005	2.170	1.398	0.859	1.275	0.703	0.406	0.260	0.379
2006	2.962	1.837	1.051	0.611	0.744	0.450	0.257	0.385
2007	2.376	2.518	1.443	0.777	0.408	0.513	0.327	0.436
2008	2.743	2.018	2.009	1.091	0.530	0.296	0.372	0.535
2009	2.347	2.332	1.641	1.565	0.777	0.390	0.228	0.639
2010	5.396	1.980	1.823	1.247	1.083	0.547	0.285	0.612

Table 3.6.9

North East: Estimates of fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1984	0.003	0.013	0.019	0.050	0.050	0.050	0.050	0.050
1985	0.003	0.015	0.022	0.058	0.058	0.058	0.058	0.058
1986	0.006	0.028	0.041	0.104	0.104	0.104	0.104	0.104
1987	0.007	0.034	0.049	0.121	0.121	0.121	0.121	0.121
1988	0.009	0.045	0.067	0.154	0.154	0.154	0.154	0.154
1989	0.012	0.064	0.097	0.220	0.220	0.220	0.220	0.220
1990	0.013	0.071	0.111	0.235	0.235	0.235	0.235	0.235
1991	0.009	0.049	0.077	0.155	0.155	0.155	0.155	0.155
1992	0.018	0.105	0.170	0.324	0.324	0.324	0.324	0.324
1993	0.013	0.077	0.127	0.237	0.237	0.237	0.237	0.237
1994	0.021	0.122	0.206	0.372	0.372	0.372	0.372	0.372
1995	0.024	0.144	0.241	0.428	0.428	0.428	0.428	0.428
1996	0.021	0.126	0.212	0.368	0.368	0.368	0.368	0.368
1997	0.019	0.113	0.190	0.318	0.318	0.318	0.318	0.318
1998	0.015	0.089	0.149	0.245	0.245	0.245	0.245	0.245
1999	0.015	0.092	0.154	0.247	0.247	0.247	0.247	0.247
2000	0.016	0.096	0.162	0.254	0.254	0.254	0.254	0.254
2001	0.014	0.084	0.143	0.225	0.225	0.225	0.225	0.225
2002	0.011	0.065	0.113	0.179	0.179	0.179	0.179	0.179
2003	0.023	0.138	0.242	0.397	0.397	0.397	0.397	0.397
2004	0.019	0.114	0.200	0.328	0.328	0.328	0.328	0.328
2005	0.021	0.126	0.221	0.371	0.371	0.371	0.371	0.371
2006	0.020	0.116	0.205	0.339	0.339	0.339	0.339	0.339
2007	0.016	0.094	0.168	0.270	0.270	0.270	0.270	0.270
2008	0.017	0.096	0.172	0.272	0.272	0.272	0.272	0.272
2009	0.022	0.127	0.229	0.356	0.356	0.356	0.356	0.356
2010	0.016	0.095	0.170	0.263	0.263	0.263	0.263	0.263

Table 3.6.10

North East: Standard errors of estimates of log fishing mortality by age and year from the final TSA run.

	3	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1984	0.258	0.268	0.276	0.214	0.214	0.214	0.214	0.214
1985	0.250	0.259	0.266	0.209	0.209	0.209	0.209	0.209
1986	0.242	0.247	0.252	0.200	0.200	0.200	0.200	0.200
1987	0.239	0.242	0.245	0.199	0.199	0.199	0.199	0.199
1988	0.236	0.237	0.239	0.197	0.197	0.197	0.197	0.197
1989	0.234	0.235	0.236	0.198	0.198	0.198	0.198	0.198
1990	0.228	0.226	0.225	0.187	0.187	0.187	0.187	0.187
1991	0.232	0.229	0.228	0.190	0.190	0.190	0.190	0.190
1992	0.224	0.221	0.218	0.177	0.177	0.177	0.177	0.177
1993	0.228	0.226	0.221	0.181	0.181	0.181	0.181	0.181
1994	0.219	0.216	0.211	0.168	0.168	0.168	0.168	0.168
1995	0.211	0.207	0.202	0.157	0.157	0.157	0.157	0.157
1996	0.213	0.209	0.203	0.160	0.160	0.160	0.160	0.160
1997	0.213	0.208	0.203	0.161	0.161	0.161	0.161	0.161
1998	0.220	0.216	0.212	0.175	0.175	0.175	0.175	0.175
1999	0.218	0.213	0.209	0.169	0.169	0.169	0.169	0.169
2000	0.218	0.214	0.210	0.170	0.170	0.170	0.170	0.170
2001	0.224	0.222	0.217	0.181	0.181	0.181	0.181	0.181
2002	0.231	0.229	0.225	0.188	0.188	0.188	0.188	0.188
2003	0.215	0.211	0.206	0.157	0.157	0.157	0.157	0.157
2004	0.223	0.219	0.213	0.169	0.169	0.169	0.169	0.169
2005	0.224	0.220	0.214	0.169	0.169	0.169	0.169	0.169
2006	0.232	0.229	0.224	0.180	0.180	0.180	0.180	0.180
2007	0.239	0.238	0.233	0.187	0.187	0.187	0.187	0.187
2008	0.248	0.248	0.244	0.195	0.195	0.195	0.195	0.195
2009	0.256	0.257	0.253	0.201	0.201	0.201	0.201	0.201
2010	0.291	0.293	0.291	0.241	0.241	0.241	0.241	0.241

Table 3.6.11

North East: Stock summary from the final TSA run.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1984	44	42	1138	8794	0.028
1985	42	45	1092	8943	0.032
1986	74	87	1260	9600	0.058
1987	72	98	1263	10550	0.068
1988	84	93	948	6966	0.089
1989	101	135	969	7910	0.127
1990	111	137	1071	14207	0.139
1991	45	90	1286	28094	0.094
1992	210	182	1629	47048	0.200
1993	183	186	2096	43852	0.147
1994	301	328	2078	26980	0.233
1995	400	419	1945	17956	0.271
1996	398	345	1635	10721	0.235
1997	313	236	1191	7749	0.207
1998	182	169	1094	8985	0.161
1999	205	149	1046	15444	0.164
2000	214	162	1239	18973	0.171
2001	157	136	1260	23493	0.151
2002	90	125	1415	22245	0.119
2003	242	260	1305	14118	0.259
2004	205	221	1277	14479	0.214
2005	246	249	1284	17965	0.240
2006	189	201	1324	24360	0.220
2007	156	179	1378	19416	0.178
2008	167	200	1491	16715	0.180
2009	251	262	1376	13544	0.237
2010	149	170	1214	14914	0.176

Table 3.7.1

Shetland: Quarterly dredge landings (UK vessels into Scotland) and market sample details 1985-2010.

	Landings (tonnes)					Numbers Aged and Measured/Boats Sampled			
	Qtr1	**Qtr2**	**Qtr3**	**Qtr4**	**Total**	**Qtr1**	**Qtr2**	**Qtr3**	**Qtr4**
1985	80	28	22	82	212	710/7	1547/15	700/7	691/6
1986	125	110	61	66	362	1923/19	1604/15	1899/19	579/6
1987	118	72	26	95	311	1356/13	844/7	905/8	1706/17
1988	123	98	59	79	359	0	749/7	1480/15	748/7
1989	91	208	130	108	537	0	1722/15	3146/26	1078/11
1990	87	167	89	104	447	712/7	2493/18	2615/19	1225/9
1991	114	94	95	102	405	1688/17	1127/11	1998/19	1307/13
1992	80	156	130	168	534	1752/17	1558/13	2278/21	834/7
1993	70	141	103	216	530	1382/10	925/8	4288/39	2372/16
1994	134	162	199	108	603	1394/13	2437/19	3375/30	2098/17
1995	178	234	174	157	743	1432/10	1034/9	4210/23	2289/15
1996	136	214	154	170	674	2837/24	1513/12	2219/19	3294/22
1997	107	168	205	453	933	1003/7	1321/10	5072/37	813/7
1998	244	156	188	332	920	1399/12	367/3	3511/27	1250/12
1999	171	182	214	181	748	1565/16	1317/12	4196/41	1201/10
2000	79	104	73	82	338	1352/13	637/6	977/7	1596/14
2001	100	138	128	125	491	1636/16	303/3	3479/33	1984/17
2002	123	143	182	111	559	940/6	1112/11	3807/35	1656/15
2003	170	200	198	188	756	1638/15	1546/12	2478/23	3654/33
2004	247	213	228	207	895	2819/24	628/6	3131/28	2120/19
2005	149	220	170	181	720	3127/26	1938/17	2897/25	816/7
2006	153	247	203	169	772	3339/29	1632/15	4081/37	2265/20
2007	205	200	210	242	857	2965/28	3881/36	3175/29	1804/17
2008	169	260	247	203	879	2194/21	1778/17	549/23	3479/33
2009	191	273	233	217	914	565/6	1807/18	1867/18	1737/17
2010	231	310	290	240	1071	1480/15	1797/18	1800/18	1435/14

Table 3.7.2

Shetland: Total catch-at-age numbers (in thousands).

	2	3	4	5	6	7	8	9	10+
1986	0	26	85	274	463	379	244	250	308
1987	3	70	224	219	200	204	177	120	325
1988	5	127	284	306	266	186	159	125	373
1989	17	126	305	346	374	411	378	273	559
1990	19	222	209	262	334	291	253	226	574
1991	9	118	208	242	267	285	316	200	609
1992	123	543	479	382	297	189	221	176	660
1993	1	113	1175	882	338	160	138	150	485
1994	0	112	868	1736	441	176	105	83	376
1995	0	108	843	1638	1221	279	133	101	309
1996	0	3	348	1120	1146	698	222	115	297
1997	0	67	804	1522	1213	911	574	192	304
1998	0	26	246	668	1076	1087	909	635	619
1999	1	39	181	426	901	927	677	426	496
2000	14	82	190	217	272	345	348	176	219
2001	0	24	723	540	260	271	344	179	480
2002	0	9	248	1089	665	304	289	211	461
2003	0	46	566	973	969	484	278	173	620
2004	0	149	772	1358	1069	708	305	138	369
2005	3	408	651	783	854	566	330	167	216
2006	11	335	904	667	659	568	395	192	495
2007	0	78	872	1078	579	438	331	169	207
2008	0	72	535	1269	808	648	519	334	430
2009	0	131	508	859	986	602	500	402	462
2010	0	144	792	1166	1098	926	629	318	339

Table 3.7.3

Shetland: Mean weights-at-age (muscle) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1986	0.015	0.019	0.020	0.021	0.022	0.023	0.026	0.033	0.031
1987	0.017	0.019	0.022	0.024	0.027	0.028	0.029	0.031	0.037
1988	0.018	0.020	0.022	0.025	0.027	0.028	0.029	0.030	0.034
1989	0.016	0.019	0.020	0.022	0.024	0.026	0.028	0.030	0.034
1990	0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.030	0.031
1991	0.014	0.018	0.020	0.023	0.024	0.026	0.027	0.029	0.031
1992	0.015	0.018	0.020	0.022	0.025	0.027	0.028	0.029	0.031
1993	0.012	0.017	0.019	0.021	0.024	0.026	0.028	0.029	0.033
1994	0.014	0.017	0.019	0.021	0.024	0.028	0.028	0.030	0.032
1995	0.014	0.016	0.019	0.022	0.022	0.027	0.030	0.030	0.032
1996	0.013	0.016	0.018	0.020	0.023	0.026	0.030	0.030	0.033
1997	0.014	0.017	0.018	0.020	0.023	0.025	0.027	0.030	0.032
1998	0.018	0.017	0.019	0.020	0.022	0.024	0.026	0.028	0.030
1999	0.018	0.017	0.019	0.021	0.023	0.025	0.027	0.030	0.033
2000	0.018	0.019	0.020	0.021	0.023	0.025	0.027	0.030	0.032
2001	0.018	0.017	0.019	0.022	0.024	0.026	0.027	0.028	0.032
2002	0.018	0.017	0.019	0.021	0.023	0.026	0.027	0.028	0.031
2003	0.018	0.018	0.020	0.023	0.025	0.027	0.028	0.030	0.034
2004	0.020	0.018	0.020	0.023	0.026	0.028	0.029	0.031	0.035
2005	0.016	0.019	0.021	0.023	0.025	0.028	0.029	0.032	0.036
2006	0.017	0.019	0.022	0.023	0.025	0.027	0.029	0.030	0.034
2007	0.018	0.018	0.020	0.025	0.027	0.030	0.032	0.035	0.038
2008	0.017	0.019	0.021	0.023	0.026	0.028	0.030	0.032	0.035
2009	0.017	0.020	0.022	0.025	0.027	0.030	0.032	0.034	0.036
2010	0.017	0.020	0.022	0.025	0.027	0.030	0.032	0.033	0.035

Table 3.7.4

Summary of Marine Scotland Science Shetland scallop dredge surveys 1988-2010.

Vessel	Cruise dates		Dredge type	No. of dredges	Width (m)	No. of hauls	No. of scallops
	From	To					
M.F.V. Cornucopia	09-May-95	20-May-95	A B	5 5	7.62	89	8342
M.F.V. Cornucopia	08-May-96	17-May-96	A B	5 5	7.62	102	8350
R.V. Clupea	28-Jan-98	11-Feb-98	A B	3 3	4.5	90	5511
R.V. Clupea	10-Mar-99	23-Mar-99	A B	3 3	4.5	80	4893
R.V. Clupea	02-Mar-00	13-Mar-00	A B	3 3	4.5	41	2855
R.V. Clupea	14-Feb-01	27-Feb-01	A B	3 3	4.5	86	5601
R.V. Clupea	04-Dec-01	17-Dec-01	A B	3 3	4.5	91	5402
R.V. Clupea	04-Mar-03	17-Mar-03	A B	3 3	4.5	91	5339
R.V. Clupea	27-Jan-04	09-Feb-04	A B	3 3	4.5	50	2447
R.V. Clupea	15-Feb-05	01-Mar-05	A B	3 3	4.5	93	5667
R.V. Clupea	09-Mar-06	27-Mar-06	A B	3 3	4.5	89	5630
R.V. Clupea	15-Mar-07	31-Mar-07	A B	3 3	4.5	82	5542
R.V. Clupea	24-Jan-08	06-Feb-08	A B	3 3	4.5	49	3219
R.V. Alba na Mara	17-Feb-09	03-Mar-09	A B	6 6	9	53	6432
R.V. Alba na Mara	15-Mar-10	27-Mar-10	A B	6 6	9	87	12870

Dredge Type A: Standard commercial dredge. 2.5’ wide. 9 tooth bar. Large belly rings.
Dredge Type B: Laboratory sampling dredge. 2.5’ wide. 11 tooth bar. Small belly rings.

Table 3.7.5

Shetland: Available research-vessel survey data by age and year (numbers $hour^{-1}metre^{-1}$).

	2	3	4	5	6	7	8	9	10+
1995	0.161	2.902	6.975	9.199	2.609	0.936	0.778	0.441	2.275
1996	0.013	1.133	4.302	7.692	5.003	0.946	0.561	0.306	1.735
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998	0.033	0.531	1.927	2.410	5.709	5.097	5.192	3.074	2.228
1999	0.072	1.202	1.099	2.208	3.282	6.404	5.480	3.416	2.585
2000	0.032	2.643	5.000	1.975	3.227	5.616	6.062	3.832	1.921
2001	0.025	1.066	8.413	3.953	1.890	2.892	3.249	2.728	3.552
2002	0.070	2.534	6.798	3.731	1.931	3.142	3.128	2.179	1.744
2003	0.009	0.611	4.298	5.423	4.914	2.422	2.273	2.539	2.427
2004	0.009	0.556	1.876	5.118	4.854	3.315	2.031	1.020	3.506
2005	0.051	3.931	3.128	4.381	4.372	3.764	2.316	1.532	2.826
2006	0.015	2.026	3.602	4.188	3.927	3.592	3.222	2.887	4.698
2007	0.032	1.489	5.316	4.710	3.892	3.312	3.216	3.158	4.338
2008	0.009	0.726	2.168	7.764	6.349	2.104	2.694	2.812	4.535
2009	0.046	1.092	2.332	4.922	4.560	3.547	2.686	0.949	6.897
2010	0.017	1.834	3.525	5.465	5.362	4.070	2.435	0.860	8.158

Table 3.7.6

Shetland: Final TSA run parameter estimates.

Parameter	Notation	Description	2011
Initial fishing mortality	F(3, 1986)	Fishing mortality at age a in year y	0.004
	F(4, 1986)		0.02
	F(7, 1986)		0.31
Survey selectivities	Φ(3)	Survey selectivity at age a	0.03
	Φ(4)		0.08
	Φ(5)		0.12
	Φ(6)		0.14
	Φ(7)		0.20
	Φ(8)		0.27
	Φ(9)		0.12
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0.15
	σ_U	Persistent changes in selection (age effect in F)	0.37
	σ_V	Transitory changes in the year effect in F	0.00
	σ_Y	Persistent changes in the year effect in F	0.26
Survey catchability standard deviations	σ_Ω	Transitory changes in survey catchability	0.16
	σ_β	Persistent changes in survey catchability	0.03
Measurement coefficients of variation	cv landings	Coefficient of variation of landings-at-age data	0.13
	cv survey	Coefficient of variation of survey data	0.33
Recruitment	η^2	Mean	7.41
	cv rec	Coefficient of variation of recruitment curve	0.35

Table 3.7.7

Shetland: Estimated population abundance by age and year (in thousands) from the final TSA run.

	3	4	5	6	7	8	9
1986	5834	4470	4350	3936	2235	1547	3505
1987	4750	4995	3762	3495	2980	1587	3603
1988	3117	3979	4024	2999	2745	2252	3982
1989	2609	2526	3150	3179	2314	2133	4766
1990	3419	2125	1893	2372	2384	1477	4512
1991	7435	2694	1652	1381	1713	1675	4195
1992	14898	6258	2098	1188	938	1152	4010
1993	12457	11752	4534	1500	789	611	3461
1994	11063	10359	9028	2454	998	533	2786
1995	10354	9321	8193	6111	1688	693	2309
1996	8225	8793	7401	5603	3936	1222	2207
1997	4871	7029	7126	5293	3805	2626	2286
1998	3507	4134	4784	4720	3430	2424	3166
1999	5453	2991	3078	3412	3113	1918	2861
2000	9391	4655	2327	2231	2139	1828	2734
2001	7822	8009	3743	1792	1610	1490	3129
2002	8342	6695	6218	2726	1301	1111	3053
2003	6947	7157	5512	4346	1751	830	2658
2004	6967	5923	5521	3819	2795	1038	1994
2005	9389	5766	4329	3489	2253	1702	1844
2006	9448	7644	4294	3029	2223	1442	2312
2007	7096	7824	5669	3064	2063	1392	2281
2008	6239	5964	5943	3860	2105	1385	2466
2009	6639	5268	4619	3886	2527	1155	2008
2010	7206	5593	4063	3184	2372	1395	1516

Table 3.7.8

Shetland: Standard errors of estimates of population abundance by age and year (in thousands) from the final TSA run.

	3	**4**	**5**	**6**	**7**	**8**	**9**
1986	0.591	0.361	0.424	0.454	0.219	0.170	0.313
1987	0.720	0.508	0.310	0.362	0.383	0.174	0.330
1988	0.637	0.621	0.431	0.254	0.299	0.317	0.390
1989	0.486	0.548	0.527	0.366	0.218	0.244	0.479
1990	0.508	0.417	0.468	0.450	0.316	0.185	0.472
1991	0.472	0.437	0.354	0.398	0.381	0.260	0.488
1992	0.664	0.404	0.374	0.303	0.337	0.312	0.512
1993	0.512	0.586	0.322	0.308	0.249	0.273	0.496
1994	0.513	0.432	0.491	0.261	0.255	0.205	0.429
1995	0.533	0.437	0.371	0.372	0.218	0.213	0.355
1996	0.422	0.460	0.383	0.296	0.269	0.170	0.260
1997	0.315	0.362	0.390	0.307	0.227	0.193	0.181
1998	0.197	0.270	0.294	0.285	0.227	0.159	0.190
1999	0.324	0.169	0.212	0.232	0.231	0.158	0.227
2000	0.519	0.278	0.135	0.167	0.178	0.174	0.244
2001	0.416	0.447	0.235	0.112	0.139	0.149	0.264
2002	0.457	0.357	0.378	0.191	0.093	0.110	0.248
2003	0.387	0.393	0.309	0.303	0.148	0.076	0.215
2004	0.436	0.332	0.325	0.239	0.233	0.107	0.181
2005	0.745	0.373	0.257	0.235	0.174	0.167	0.169
2006	0.843	0.651	0.299	0.205	0.181	0.132	0.185
2007	0.777	0.724	0.546	0.250	0.178	0.146	0.226
2008	0.834	0.664	0.622	0.455	0.210	0.149	0.268
2009	1.285	0.711	0.560	0.536	0.385	0.156	0.282
2010	1.730	1.100	0.608	0.493	0.456	0.303	0.338

Table 3.7.9

Shetland: Estimates of fishing mortality by age and year from the final TSA run.

	3	**4**	**5**	**6**	**7**	**8**	**9**
1986	0.005	0.023	0.066	0.128	0.171	0.159	0.160
1987	0.022	0.066	0.068	0.091	0.131	0.112	0.113
1988	0.040	0.072	0.086	0.099	0.096	0.100	0.127
1989	0.037	0.087	0.109	0.136	0.298	0.291	0.260
1990	0.062	0.075	0.104	0.142	0.201	0.207	0.205
1991	0.022	0.067	0.120	0.141	0.201	0.216	0.222
1992	0.087	0.170	0.148	0.191	0.187	0.195	0.222
1993	0.023	0.114	0.446	0.208	0.178	0.179	0.182
1994	0.017	0.073	0.240	0.205	0.161	0.162	0.155
1995	0.013	0.080	0.221	0.285	0.172	0.162	0.154
1996	0.006	0.059	0.183	0.220	0.229	0.221	0.221
1997	0.013	0.234	0.252	0.273	0.263	0.242	0.236
1998	0.009	0.145	0.184	0.263	0.417	0.494	0.529
1999	0.008	0.095	0.171	0.312	0.381	0.417	0.402
2000	0.009	0.068	0.102	0.175	0.212	0.235	0.221
2001	0.005	0.103	0.167	0.158	0.219	0.276	0.258
2002	0.003	0.044	0.207	0.293	0.296	0.328	0.288
2003	0.009	0.108	0.213	0.291	0.370	0.439	0.400
2004	0.039	0.153	0.303	0.371	0.345	0.359	0.336
2005	0.055	0.142	0.192	0.291	0.286	0.254	0.258
2006	0.038	0.147	0.186	0.229	0.314	0.334	0.355
2007	0.023	0.124	0.232	0.225	0.247	0.273	0.234
2008	0.018	0.101	0.275	0.267	0.447	0.577	0.461
2009	0.021	0.105	0.219	0.343	0.443	0.584	0.582
2010	0.022	0.164	0.418	0.519	0.571	0.626	0.608

Table 3.7.10

Shetland: Standard errors of estimates of log fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9
1986	0.151	0.146	0.140	0.158	0.169	0.192	0.170
1987	0.151	0.147	0.145	0.146	0.164	0.200	0.188
1988	0.145	0.141	0.158	0.177	0.150	0.165	0.152
1989	0.137	0.139	0.148	0.165	0.154	0.171	0.142
1990	0.137	0.138	0.141	0.150	0.152	0.172	0.160
1991	0.137	0.135	0.144	0.147	0.137	0.153	0.140
1992	0.133	0.126	0.133	0.143	0.132	0.145	0.127
1993	0.141	0.133	0.117	0.147	0.140	0.152	0.120
1994	0.140	0.139	0.126	0.136	0.137	0.153	0.117
1995	0.141	0.142	0.121	0.119	0.122	0.140	0.116
1996	0.135	0.137	0.135	0.130	0.118	0.143	0.127
1997	0.130	0.118	0.122	0.129	0.119	0.138	0.151
1998	0.127	0.133	0.138	0.137	0.118	0.140	0.133
1999	0.131	0.133	0.135	0.133	0.130	0.150	0.139
2000	0.139	0.137	0.144	0.152	0.142	0.148	0.140
2001	0.135	0.130	0.132	0.145	0.131	0.137	0.123
2002	0.137	0.144	0.127	0.130	0.132	0.146	0.122
2003	0.133	0.129	0.126	0.131	0.124	0.145	0.122
2004	0.134	0.128	0.121	0.122	0.124	0.150	0.135
2005	0.154	0.136	0.143	0.141	0.134	0.145	0.145
2006	0.164	0.142	0.148	0.156	0.142	0.157	0.151
2007	0.161	0.164	0.147	0.154	0.152	0.164	0.155
2008	0.165	0.182	0.168	0.159	0.139	0.156	0.146
2009	0.204	0.219	0.214	0.187	0.180	0.202	0.192
2010	0.259	0.252	0.260	0.248	0.241	0.256	0.254

Table 3.7.11

Shetland: Stock summary from the final TSA run (in thousands).

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1986	51	46	582	5834	0.072
1987	44	48	642	4750	0.075
1988	50	50	605	3117	0.085
1989	74	83	521	2609	0.111
1990	61	59	445	3419	0.107
1991	59	54	477	7435	0.109
1992	72	82	649	14898	0.170
1993	79	88	715	12457	0.256
1994	88	81	764	11063	0.173
1995	105	98	797	10354	0.195
1996	93	95	777	8225	0.154
1997	128	131	711	4871	0.253
1998	128	132	575	3507	0.197
1999	104	102	513	5453	0.193
2000	46	54	560	9391	0.115
2001	69	69	589	7822	0.142
2002	79	80	618	8342	0.181
2003	106	111	662	6947	0.204
2004	123	128	646	6967	0.275
2005	99	99	662	9389	0.208
2006	107	105	700	9448	0.187
2007	99	101	699	7096	0.193
2008	122	131	664	6239	0.214
2009	126	133	652	6639	0.222
2010	149	156	622	7206	0.367

Table 3.8.1

East Coast: Quarterly dredge landings (UK vessels into Scotland) and market sample details, 1985-2010.

	Landings (tonnes)					Numbers Aged and Measured/Boats Sampled			
	Qtr1	Qtr2	Qtr3	Qtr4	Total	Qtr1	Qtr2	Qtr3	Qtr4
1985					0	0	0	0	0
1986					0	0	0	0	0
1987					0	0	0	0	0
1988					0	0	0	0	0
1989	1	0	0	0	1	1	0	0	0
1990	0	2	0	0	2	0	0	0	0
1991	0	90	445	5	540	0	594/4	1433/8	0
1992	68	151	100	2	321	550/4	226/1	0	169/1
1993	25	118	476	8	626	459/2	288/1	2336/10	245/1
1994	80	1142	513	78	1813	227/1	6954/26	1808/6	866/3
1995	351	850	561	139	1902	3821/15	6380/26	5851/24	1249/5
1996	238	345	43	53	679	1126/5	3335/16	760/3	698/3
1997	131	457	74	53	715	832/4	2626/11	176/1	415/2
1998	276	608	75	47	1006	320/3	850/5	383/2	206/1
1999	379	857	276	307	1819	116/1	1326/7	0	1497/10
2000	222	341	112	51	726	106/1	688/5	0	352/2
2001	61	201	24	11	299	0	0	0	0
2002	80	220	83	32	416	0	340/2	0	0
2003	89	227	293	209	818	0	145/1	570/2	0
2004	660	1134	261	384	2439	681/3	1356/7	0	258/1
2005	336	456	513	266	1571	219/1	543/3	277/1	0
2006	314	966	291	199	1769	149/1	479/2	469/2	0
2007	405	1061	954	174	2593	788/3	1498/6	1305/6	669/3
2008	272	618	697	256	1843	1285/5	936/4	1303/6	455/2
2009	200	554	623	151	1528	0	1929/7	168/1	1003/4
2010	188	920	569	80	1757	515/2	562/3	0	210/1

Table 3.8.2

East Coast: Total catch-at-age numbers (in thousands).

	2	3	4	5	6	7	8	9	10+
1991	109	191	198	234	165	262	208	188	862
1992	1	13	282	232	250	220	157	109	496
1993	27	337	1711	826	255	172	90	75	189
1994	0	361	3528	4365	1343	376	205	146	553
1995	7	246	1788	3144	3280	1137	541	218	589
1996	2	52	357	755	1181	844	197	46	155
1997	5	69	520	732	1022	938	353	66	94
1998	0	20	103	486	809	1295	939	352	270
1999	0	204	367	518	781	1225	1546	1641	2547
2000	0	15	343	108	101	290	597	667	1177
2001	0	0	5	9	9	36	68	74	98
2002	0	559	547	84	32	65	176	202	238
2003	0	304	2475	918	123	201	178	195	359
2004	0	18	1344	4175	2986	1077	662	543	2013
2005	0	298	786	2169	2793	844	253	193	805
2006	0	190	537	1474	2577	2392	1513	509	777
2007	0	916	6912	3116	1724	1066	540	236	686
2008	43	812	2590	3060	1246	889	583	299	519
2009	10	284	1293	2016	1449	1174	852	451	832
2010	0	7	436	1770	4335	1538	886	449	355

Table 3.8.3

East Coast: Mean weights-at-age (muscle) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1991	0.015	0.019	0.020	0.023	0.025	0.027	0.029	0.030	0.034
1992	0.013	0.015	0.015	0.020	0.022	0.023	0.024	0.027	0.027
1993	0.013	0.015	0.017	0.021	0.025	0.029	0.031	0.032	0.036
1994	0.014	0.015	0.017	0.019	0.023	0.027	0.028	0.030	0.033
1995	0.015	0.016	0.018	0.019	0.020	0.023	0.026	0.027	0.030
1996	0.014	0.015	0.017	0.020	0.022	0.025	0.029	0.033	0.033
1997	0.014	0.015	0.018	0.020	0.022	0.025	0.028	0.030	0.036
1998	0.014	0.017	0.019	0.023	0.026	0.028	0.031	0.034	0.036
1999	0.014	0.018	0.020	0.021	0.022	0.023	0.025	0.026	0.027
2000	0.014	0.016	0.020	0.021	0.024	0.023	0.025	0.027	0.031
2001	0.014	0.017	0.015	0.019	0.020	0.022	0.024	0.026	0.028
2002	0.014	0.016	0.019	0.027	0.027	0.030	0.032	0.033	0.037
2003	0.014	0.015	0.018	0.020	0.024	0.026	0.028	0.030	0.031
2004	0.014	0.013	0.016	0.019	0.021	0.024	0.028	0.030	0.032
2005	0.014	0.012	0.015	0.019	0.023	0.026	0.028	0.030	0.036
2006	0.014	0.015	0.016	0.017	0.020	0.022	0.024	0.026	0.029
2007	0.014	0.015	0.017	0.021	0.025	0.029	0.032	0.032	0.038
2008	0.015	0.018	0.019	0.021	0.024	0.027	0.028	0.031	0.036
2009	0.015	0.016	0.017	0.019	0.022	0.025	0.027	0.031	0.035
2010	0.015	0.015	0.017	0.019	0.021	0.022	0.024	0.025	0.031

Table 3.8.4

East Coast: Available research-vessel survey data by age and year (numbers $hour^{-1}metre^{-1}$).

	2	3	4	5	6	7	8	9	10+
1994	0.01	0.24	4.68	13.36	4.32	1.36	0.93	0.61	2.28
1995	0.01	0.80	1.10	4.39	6.01	1.18	0.51	0.18	0.72
1996	0.00	0.08	2.65	1.21	4.51	4.53	1.01	0.33	0.76
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998	0.00	0.38	0.27	0.49	0.43	2.64	2.33	4.26	4.32
1999	0.10	0.62	0.38	0.32	0.33	2.46	2.18	2.48	2.08
2000	0.60	0.96	0.79	0.22	0.44	0.84	2.55	3.04	3.63
2001	0.03	3.16	1.21	0.65	0.35	0.67	1.71	2.41	2.94
2002	0.02	3.85	6.16	1.16	0.79	0.50	1.28	2.05	2.50
2003	0.00	1.27	5.23	4.37	1.58	0.79	0.96	0.79	3.58
2004	0.20	1.42	2.74	4.98	3.80	0.78	0.59	1.00	3.13
2005	0.11	2.53	2.20	3.14	4.55	3.32	0.84	0.58	3.51
2006	0.00	5.88	3.84	3.19	3.13	3.35	2.49	1.88	2.72
2007	0.02	0.68	3.80	4.84	2.89	2.66	2.10	2.01	3.38
2008	0.00	1.07	4.52	8.40	3.50	2.23	1.60	0.62	3.68
2009	0.00	0.62	2.42	4.13	5.43	3.27	2.02	0.88	4.77
2010	0.00	0.78	2.05	2.95	3.94	4.08	2.28	0.83	4.08

Table 3.9.1

Orkney: Quarterly dredge landings (UK vessels into Scotland) and market sample details 1985-2010.

	Landings (tonnes)					Numbers Aged and Measured/Boats Sampled			
	Qtr1	Qtr2	Qtr3	Qtr4	Total	Qtr1	Qtr2	Qtr3	Qtr4
1985	3	0	1	0	4	0	0	0	0
1986	4	88	9	7	109	0	0	0	0
1987	9	21	13	78	120	0	0	0	0
1988	4	26	5	0	35	0	0	0	0
1989	7	43	235	8	293	0	0	441/2	0
1990	1	157	12	6	176	0	249/1	0	0
1991	29	86	9	0	124	0	389/2	502/2	0
1992	0	0	0	26	26	0	0	0	0
1993	0	0	0	0	0	0	730/3	0	0
1994	28	34	42	6	110	0	0	487/2	338/2
1995	33	72	37	72	214	0	659/5	188/1	332/1
1996	61	81	31	41	214	454/4	559/2	0	293/2
1997	25	47	41	33	146	0	0	1613/2	172/1
1998	48	52	25	39	163	0	500/3	130/1	275/2
1999	42	152	55	42	291	432/2	1046/4	166/1	0
2000	30	23	24	22	99	0	0	361/2	451/2
2001	49	54	265	74	442	174/1	0	1087/5	303/2
2002	15	119	33	101	268	0	172/1	171/1	321/2
2003	78	74	15	8	175	0	175/1	0	174/1
2004	29	55	26	39	148	0	681/3	0	0
2005	65	82	22	51	220	0	0	0	0
2006	50	19	42	6	117	0	0	0	0
2007	29	37	12	26	104	239/1	351/2	0	0
2008	34	74	61	14	184	0	709/4	81/1	278/1
2009	25	105	12	50	192	0	491/4	0	599/4
2010	30	59	37	49	176	331/2	414/3	499/4	0

8. Figures

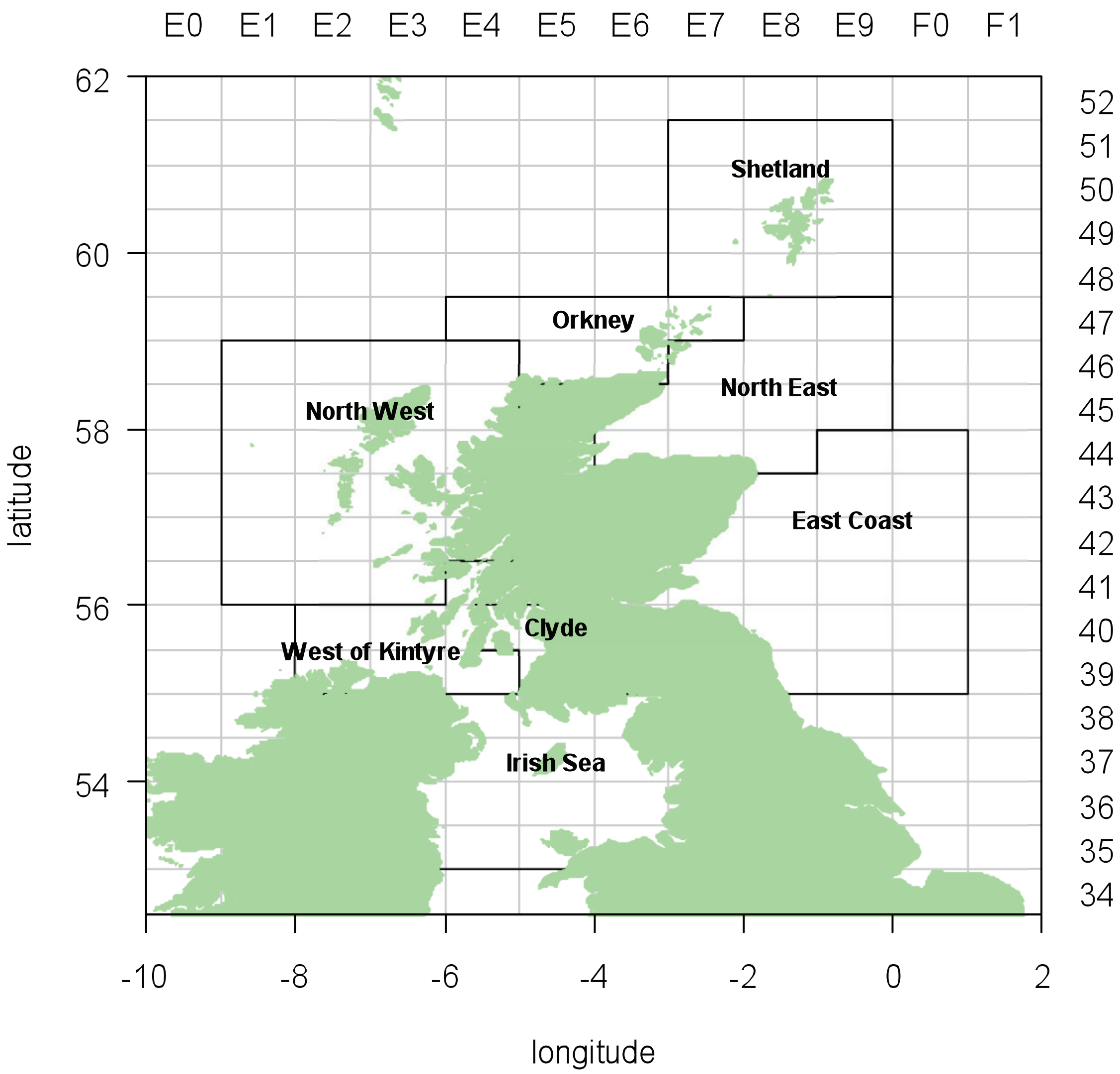


Figure 2.1.1: Scottish scallop assessment areas.

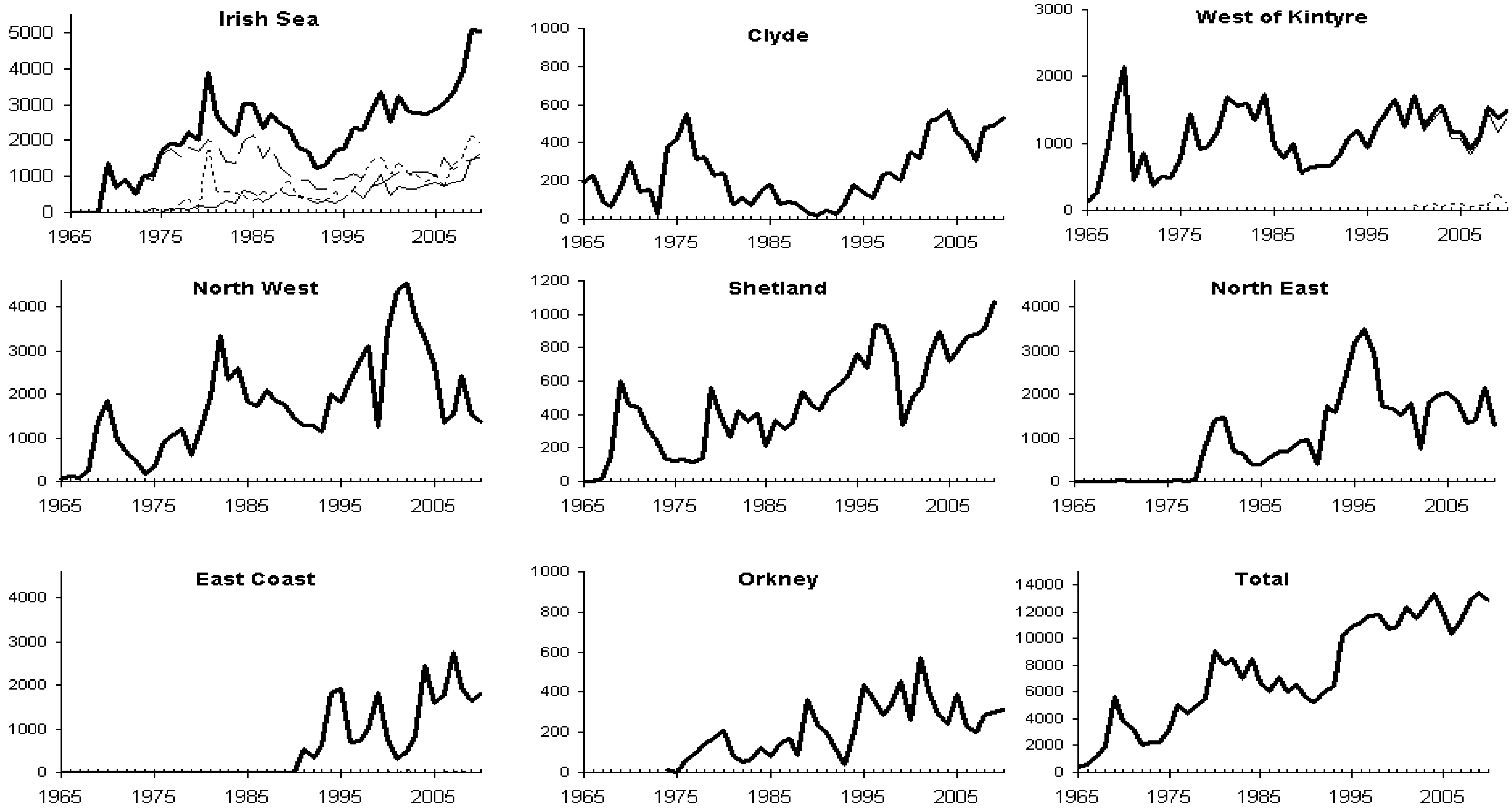


Figure 3.1.1: Total reported landings by assessment area (tonnes). The Irish Sea and West of Kintyre also have landings into countries other than Scotland (solid line: Scotland, dotted line: UK (non Scotland), dashed line: Isle of Man). Some UK (non Scotland) landings pre 2000 may have been taken elsewhere in Division VIIa (i.e. out-with the Irish Sea assessment area). Note differences in scales of landings.

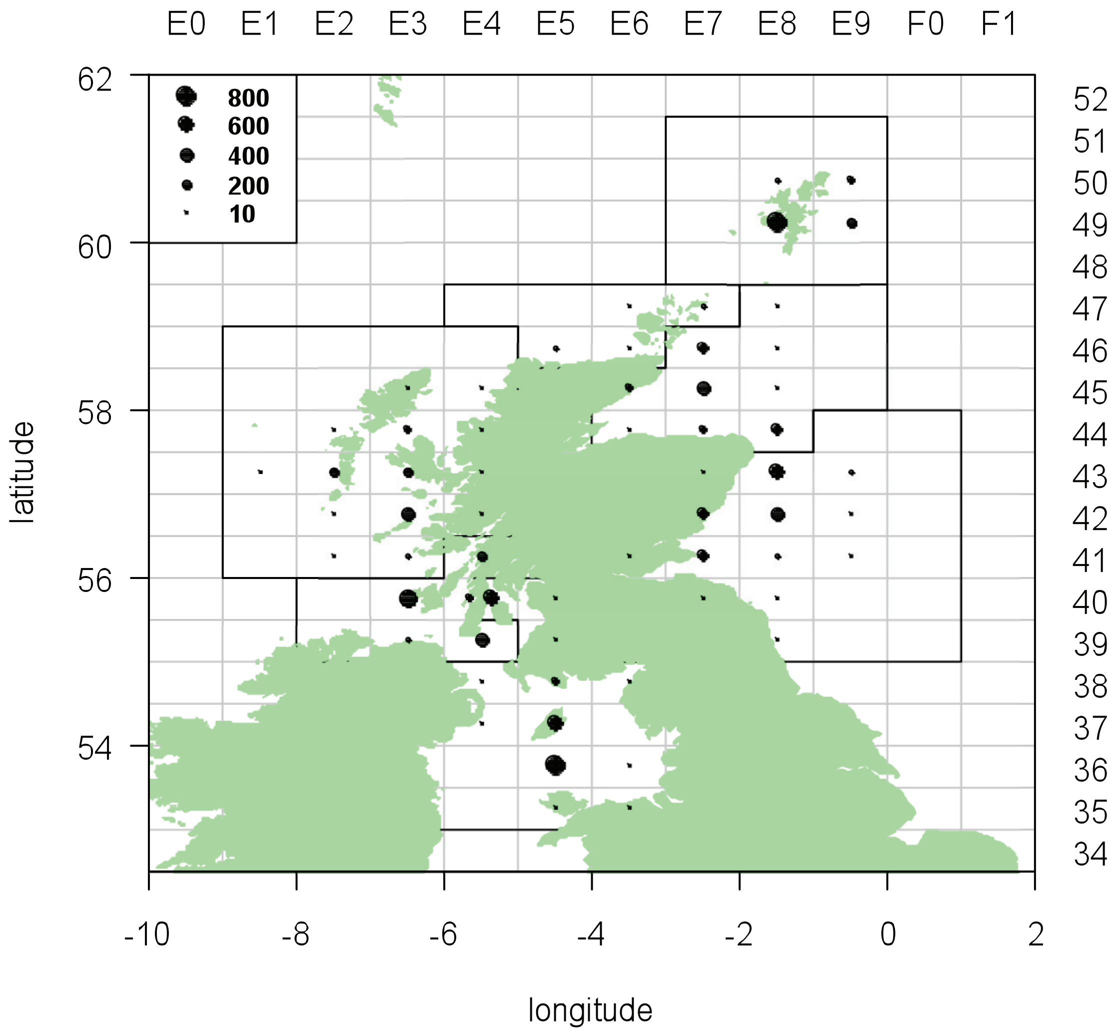


Figure 3.1.2: Spatial distribution of dredge caught scallop landings (tonnes) from Scottish scallop assessment areas into Scotland in 2010. Landings from statistical rectangle 40E4 are split into and east and west component.

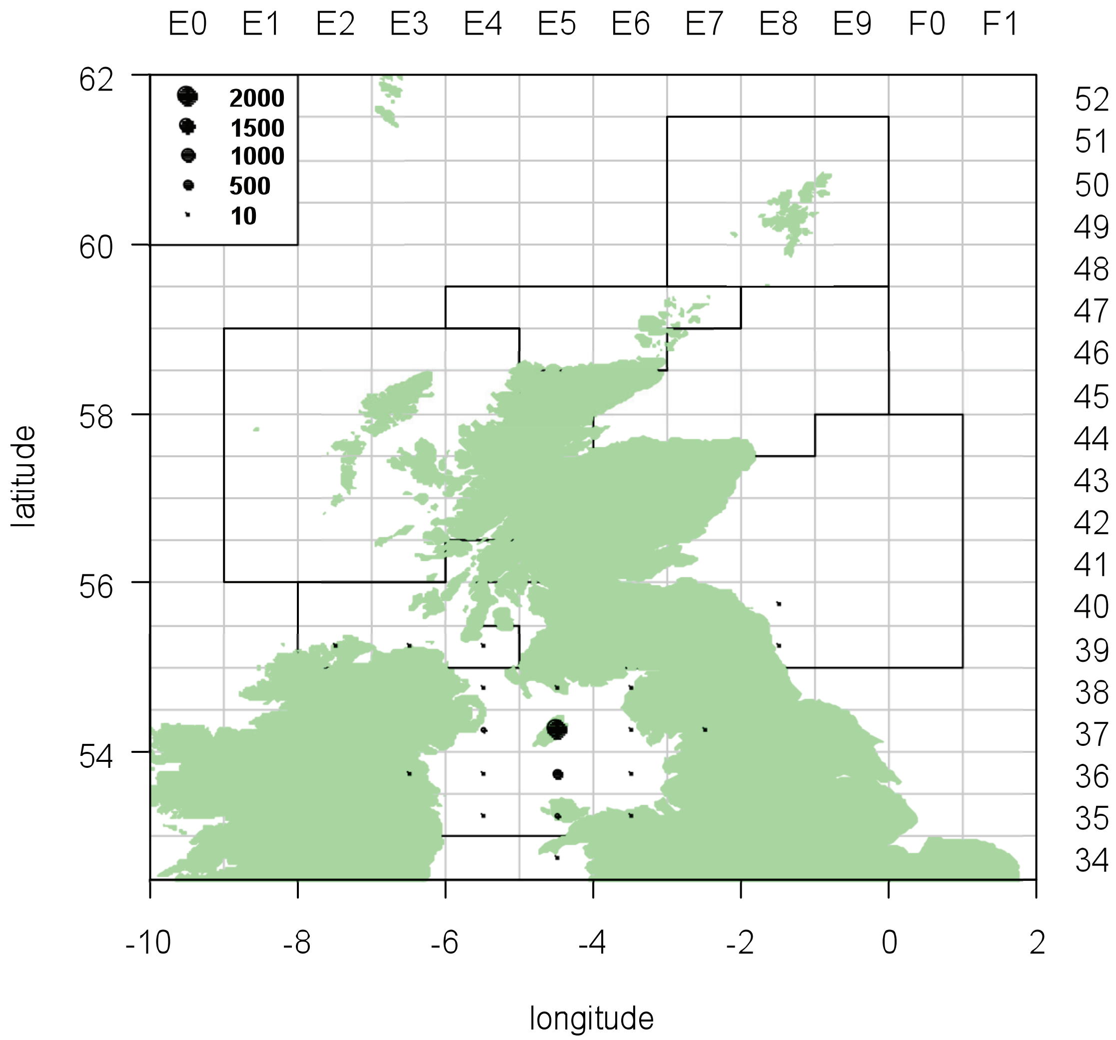


Figure 3.1.3: Spatial distribution of dredge caught scallop landings (tonnes) from Scottish scallop assessment areas into ports outside Scotland in 2010.

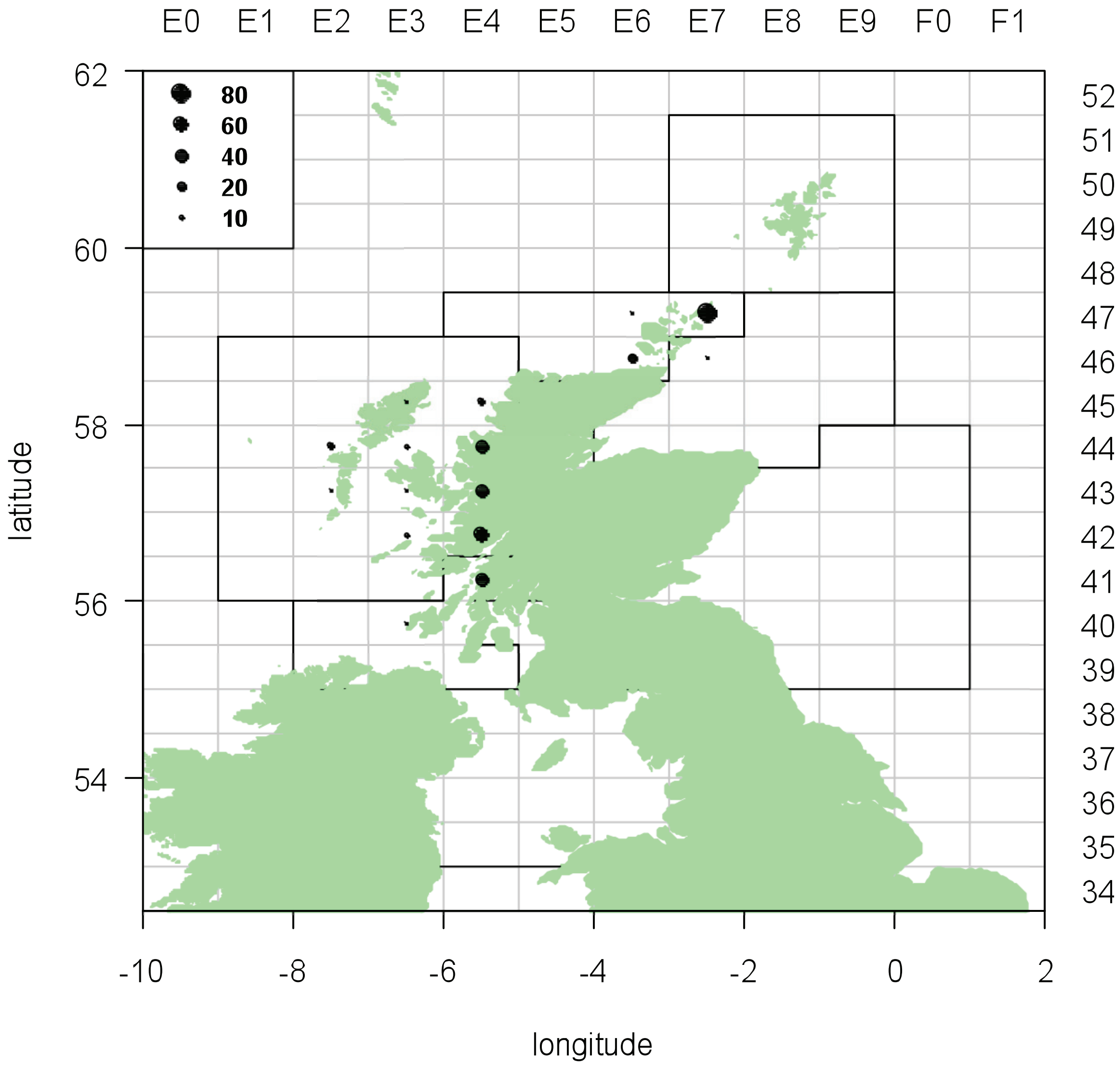


Figure 3.1.4: Spatial distribution of dive caught scallop landings (tonnes) in 2010.

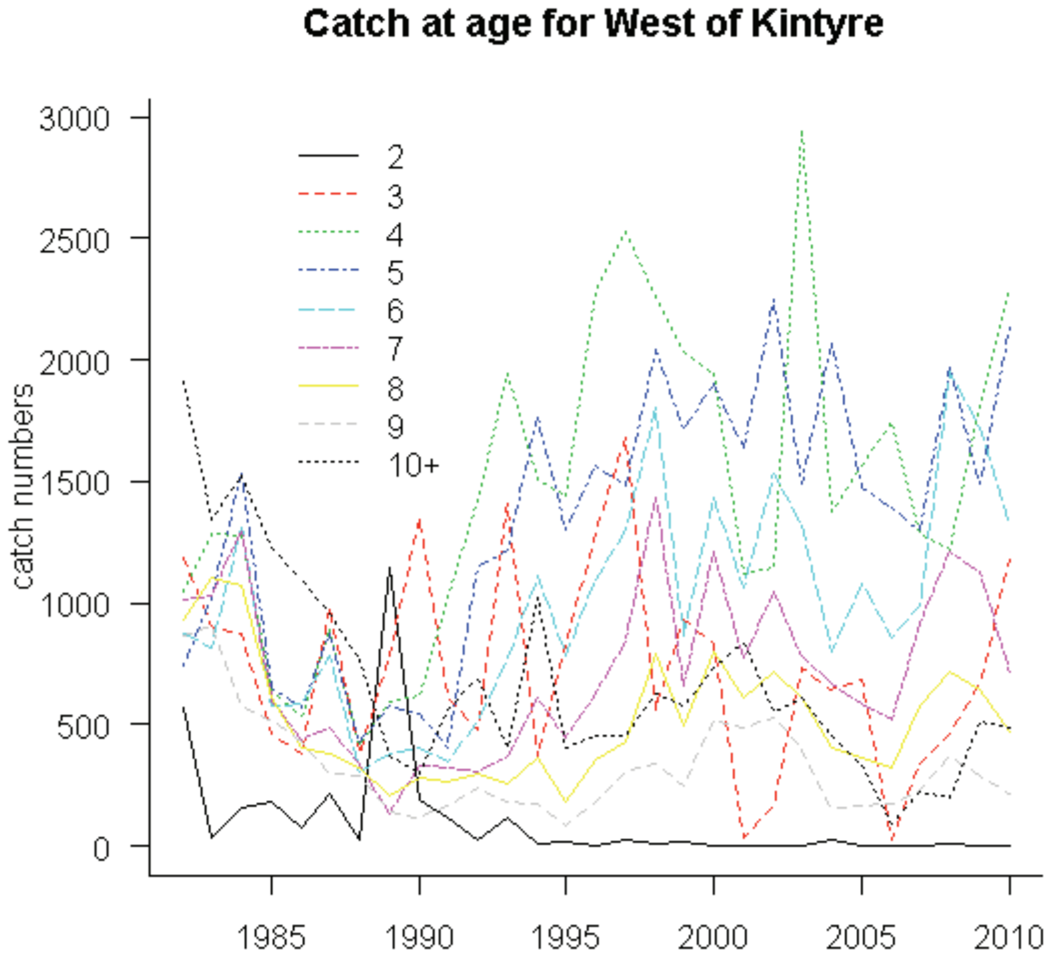


Figure 3.2.1: West of Kintyre. Total catch-at-age numbers (in thousands).

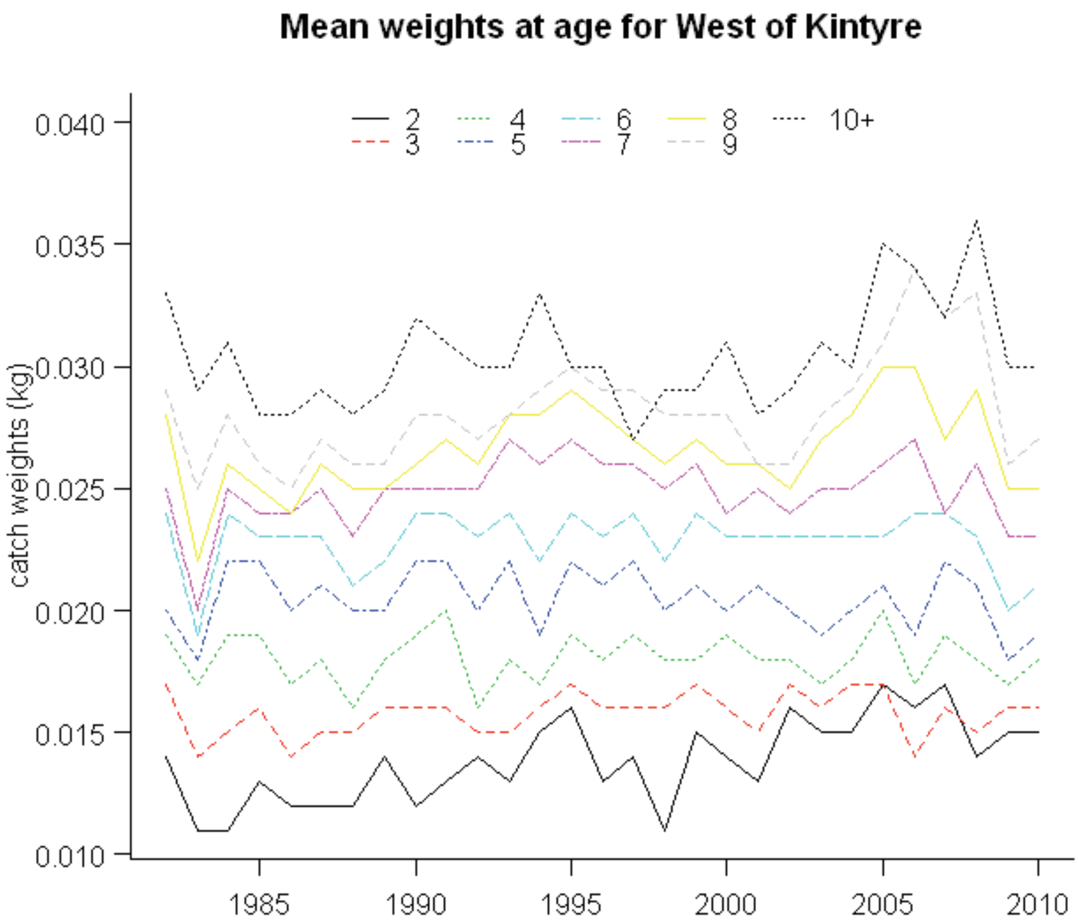


Figure 3.2.2: West of Kintyre. Mean weights-at-age (kg) in total catch (also used for stock weights).

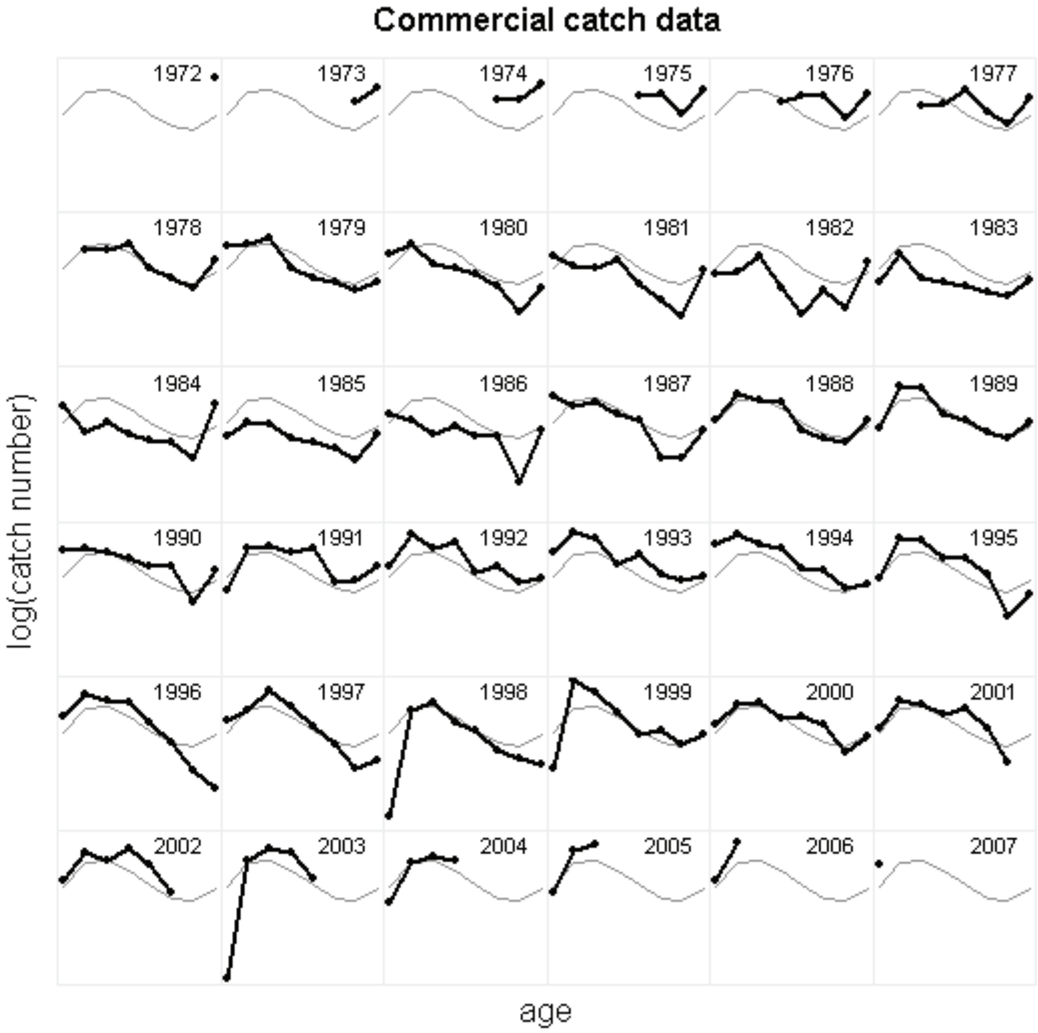
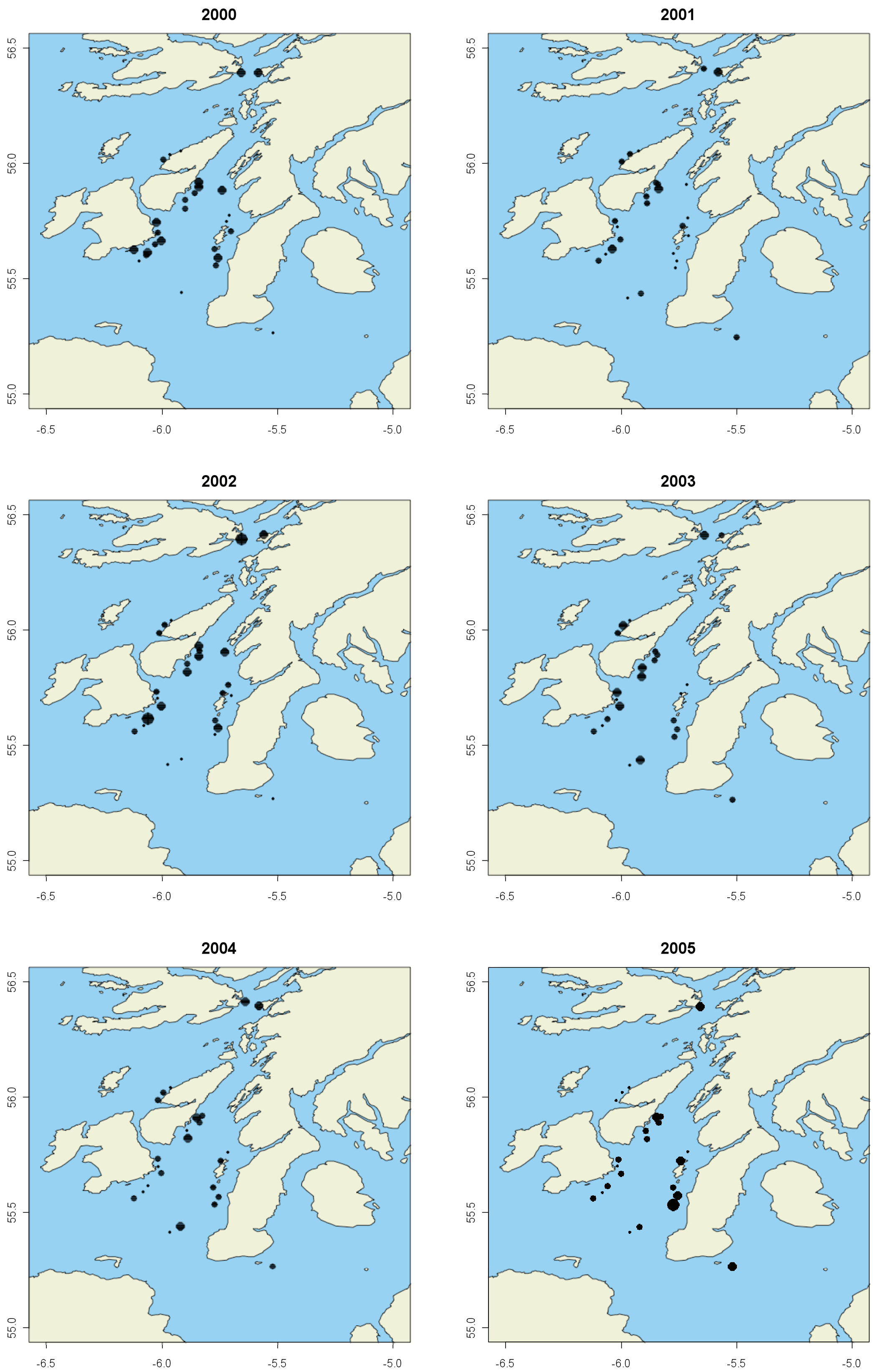


Figure 3.2.3: West of Kintyre. Catch curves from commercial data (ages 3 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.


2000
2001
2002
2003
2004
2005
56.5
56.0
55.5
55.0
-6.5
-6.0
-5.5
-5.0

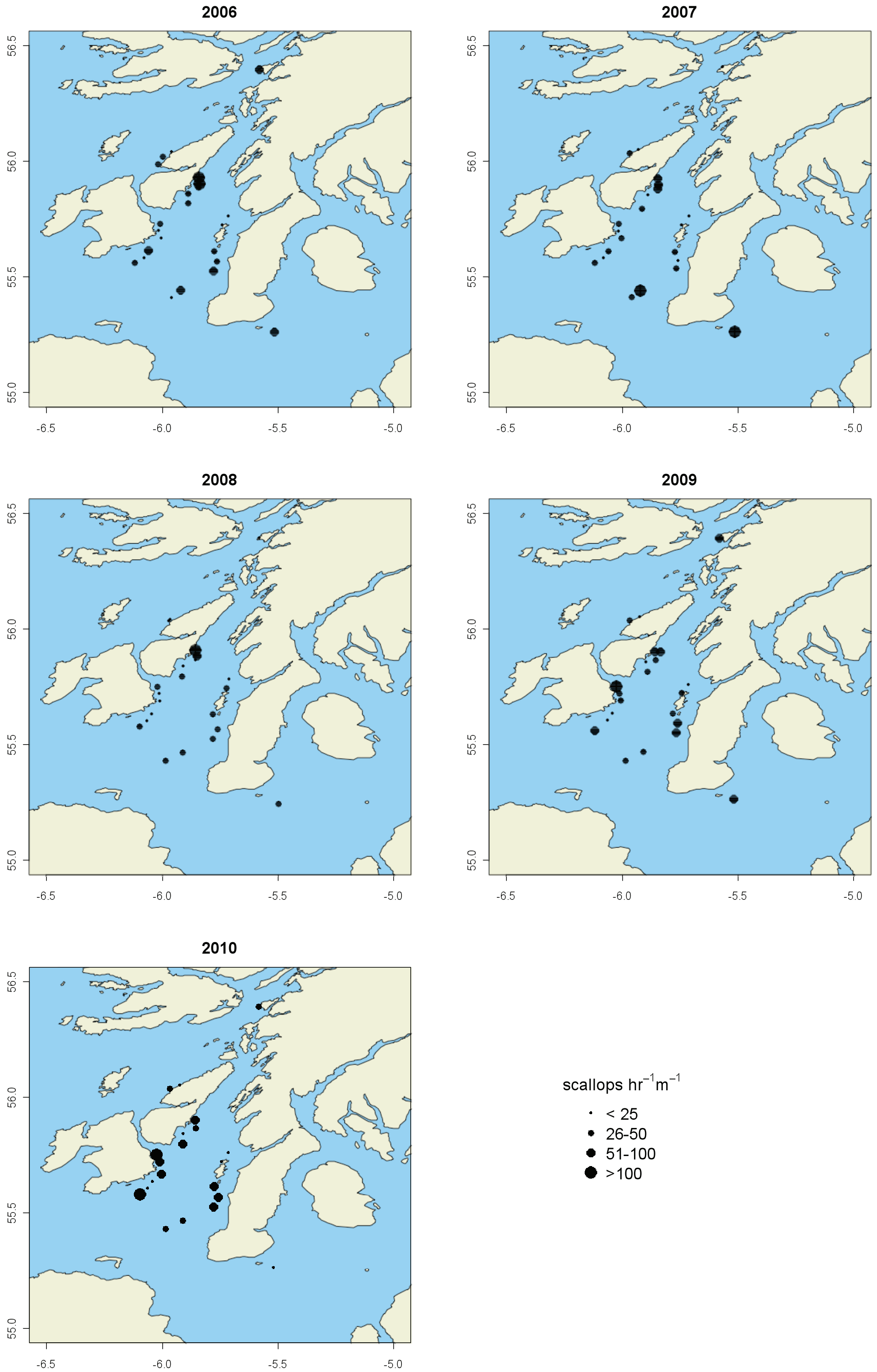


Figure 3.2.4: West of Kintyre. Distribution of dredge survey catch rates (2000-2010).

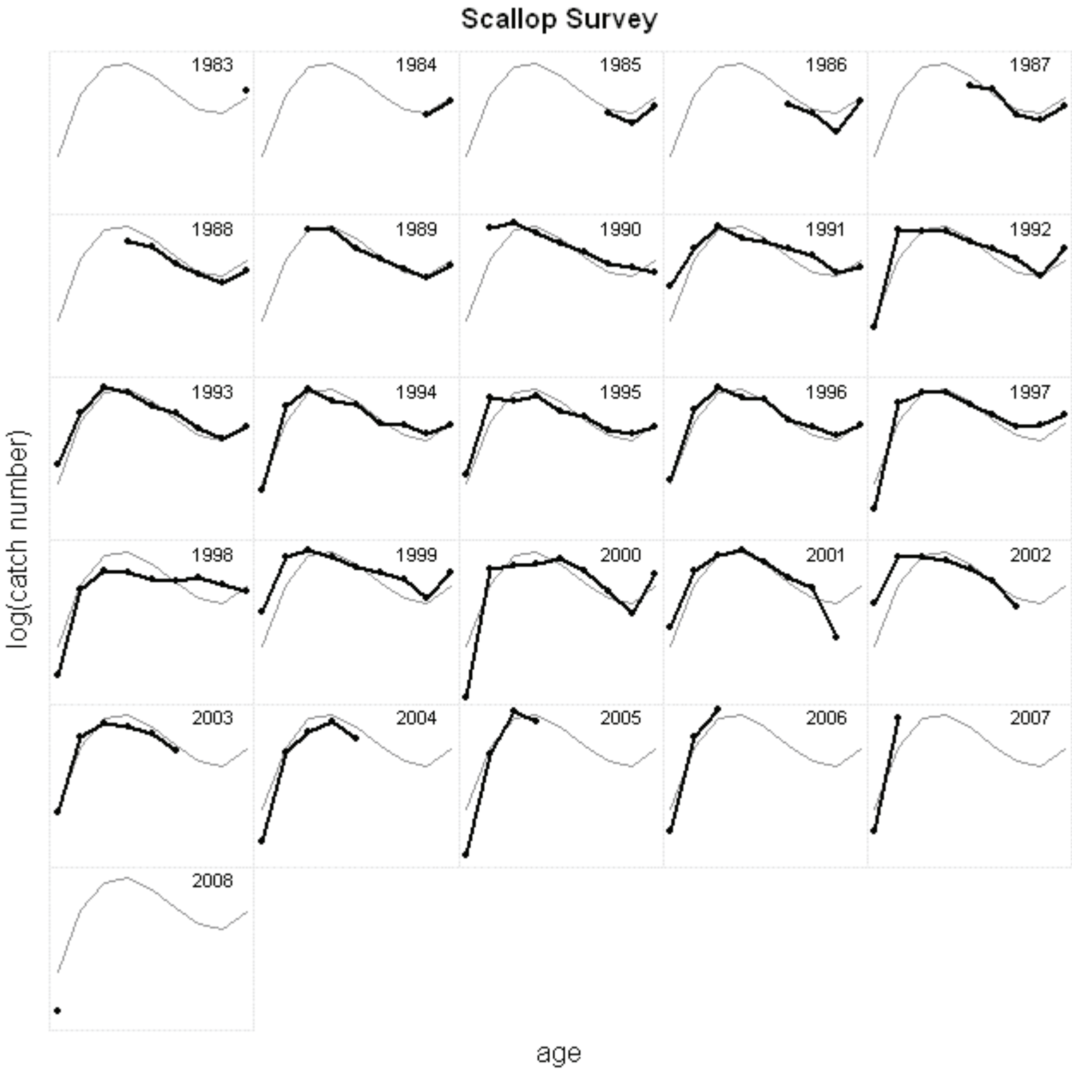


Figure 3.2.5: West of Kintyre. Catch curves from survey data (ages 2 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.

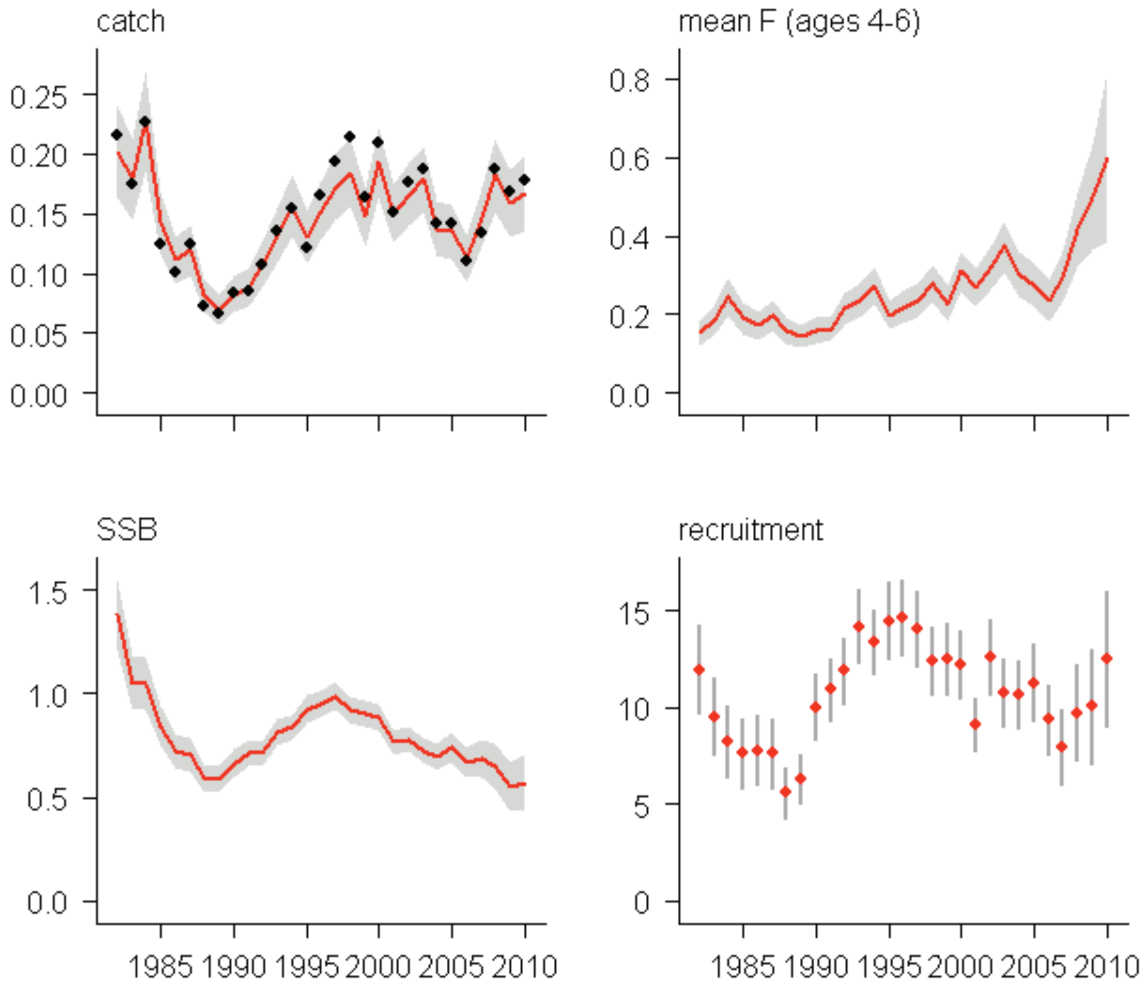


Figure 3.2.6: West of Kintyre. TSA stock summaries from the final TSA run. Catch and SSB are in terms of muscle weight (thousand tonnes) and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals.

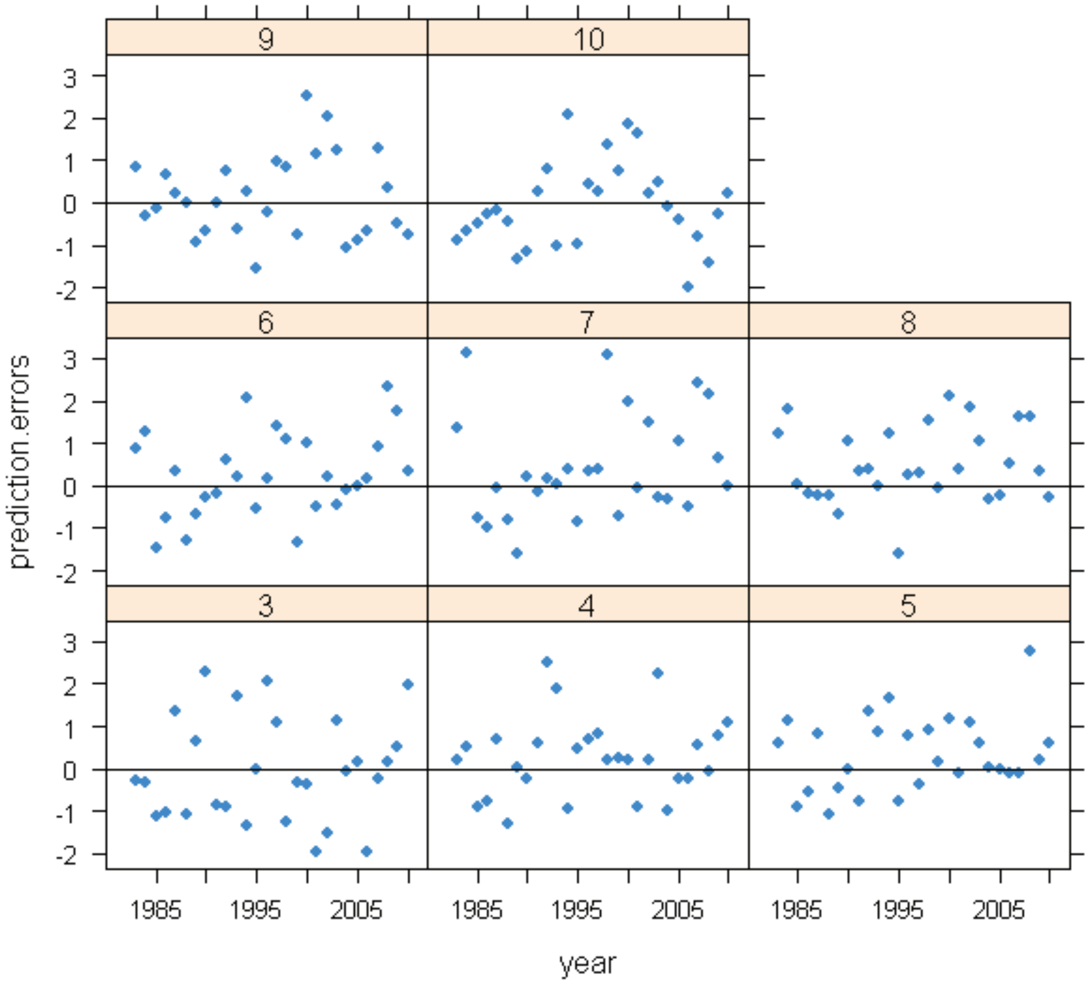


Figure 3.2.7: West of Kintyre. Standardised catch prediction errors by age from the final TSA run.

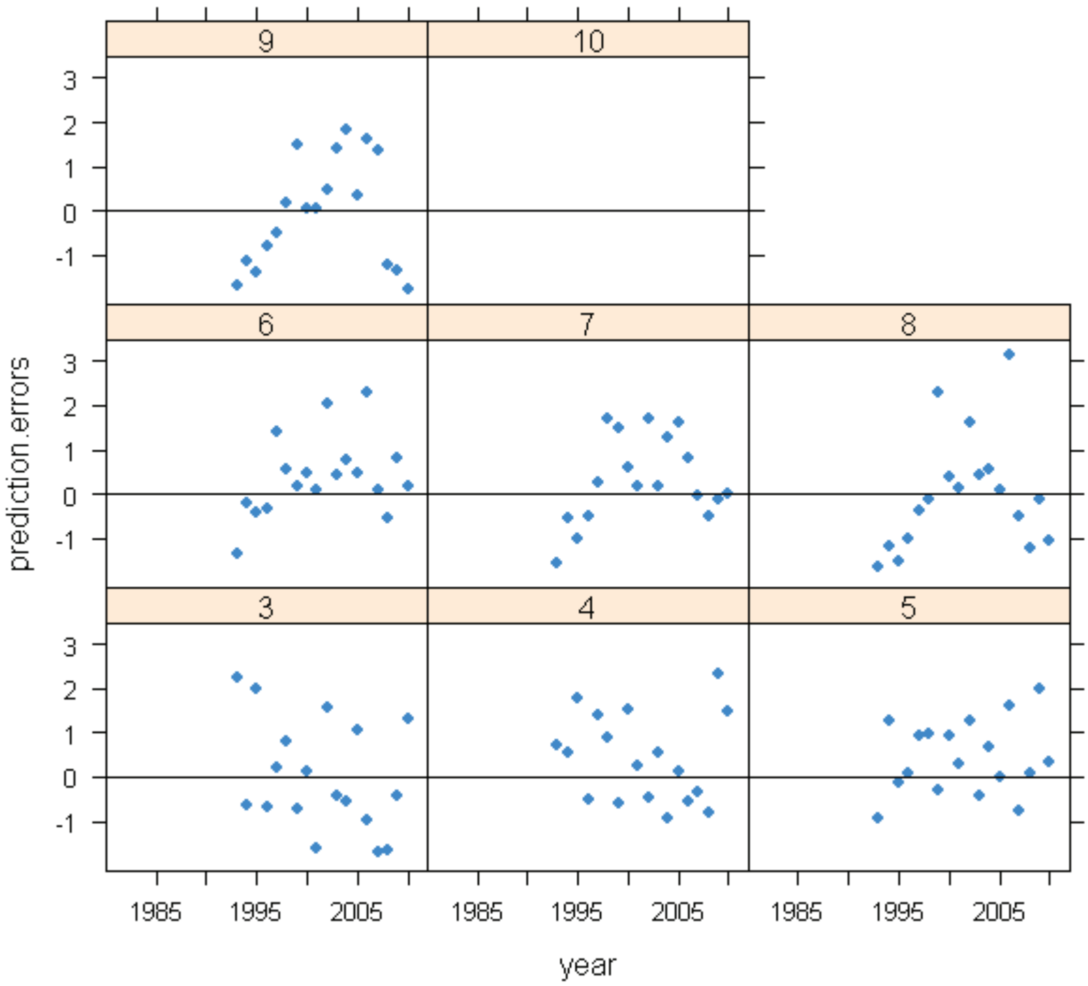


Figure 3.2.8: West of Kintyre. Standardised survey prediction errors by age from the final TSA run.

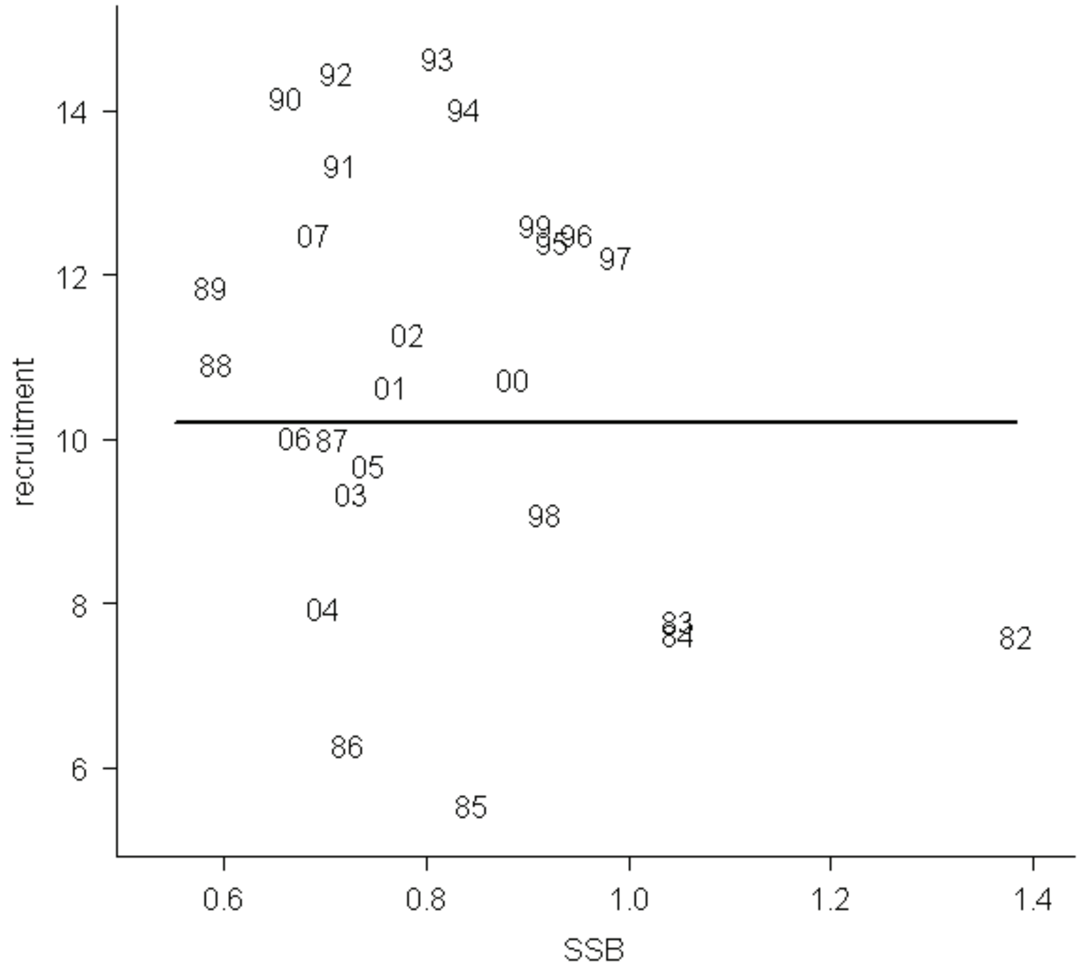


Figure 3.2.9: West of Kintyre. Stock-recruit plot from the final TSA run. Recruitment (age 3) is in millions and SSB in thousand tonnes muscle weight. Values are labelled with year class.

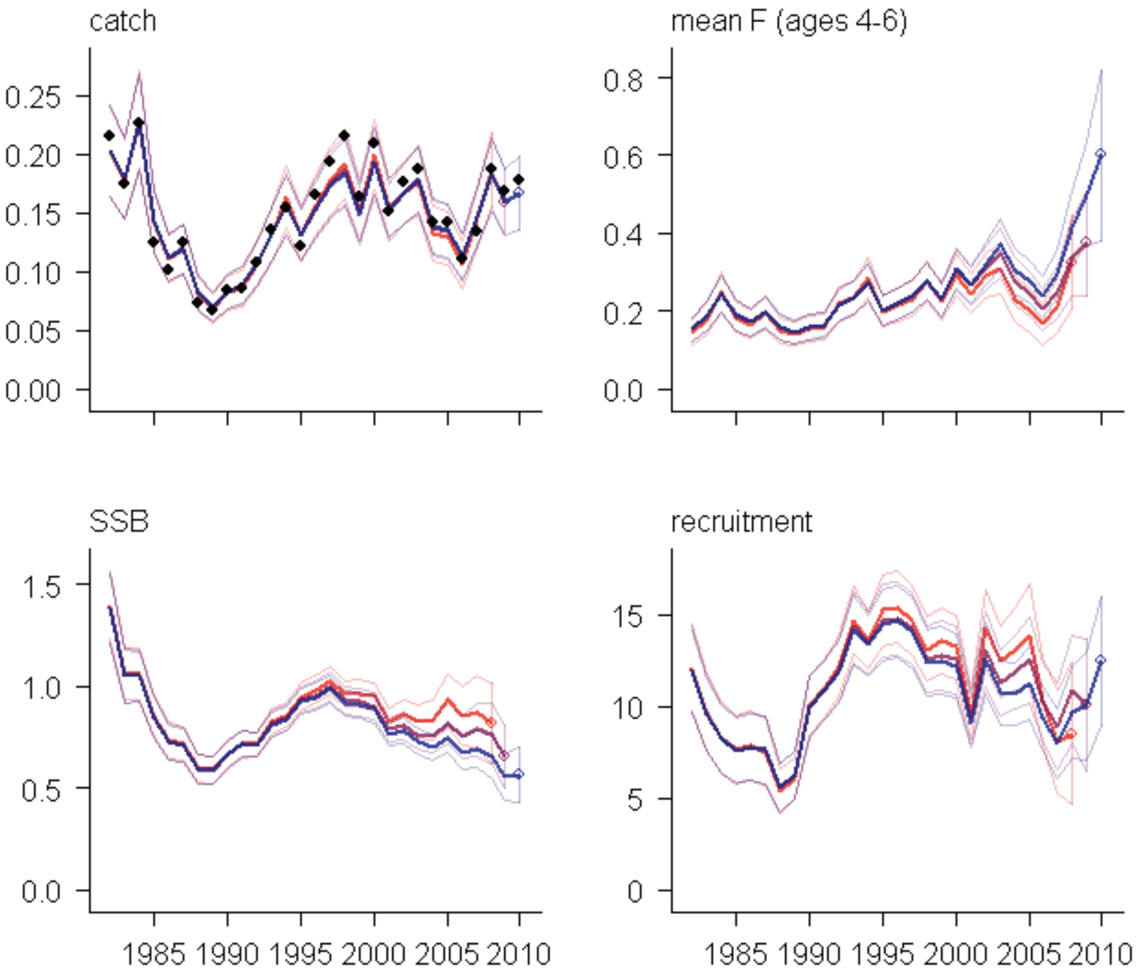


Figure 3.2.10: West of Kintyre. Estimates of catch, mean $F_{4\text{-}6}$, SSB and recruitment with 95 % confidence intervals (pale lines) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment (age 3) in millions. Blue line: data to 2010, maroon line: data to 2009 and red line: data to 2008.

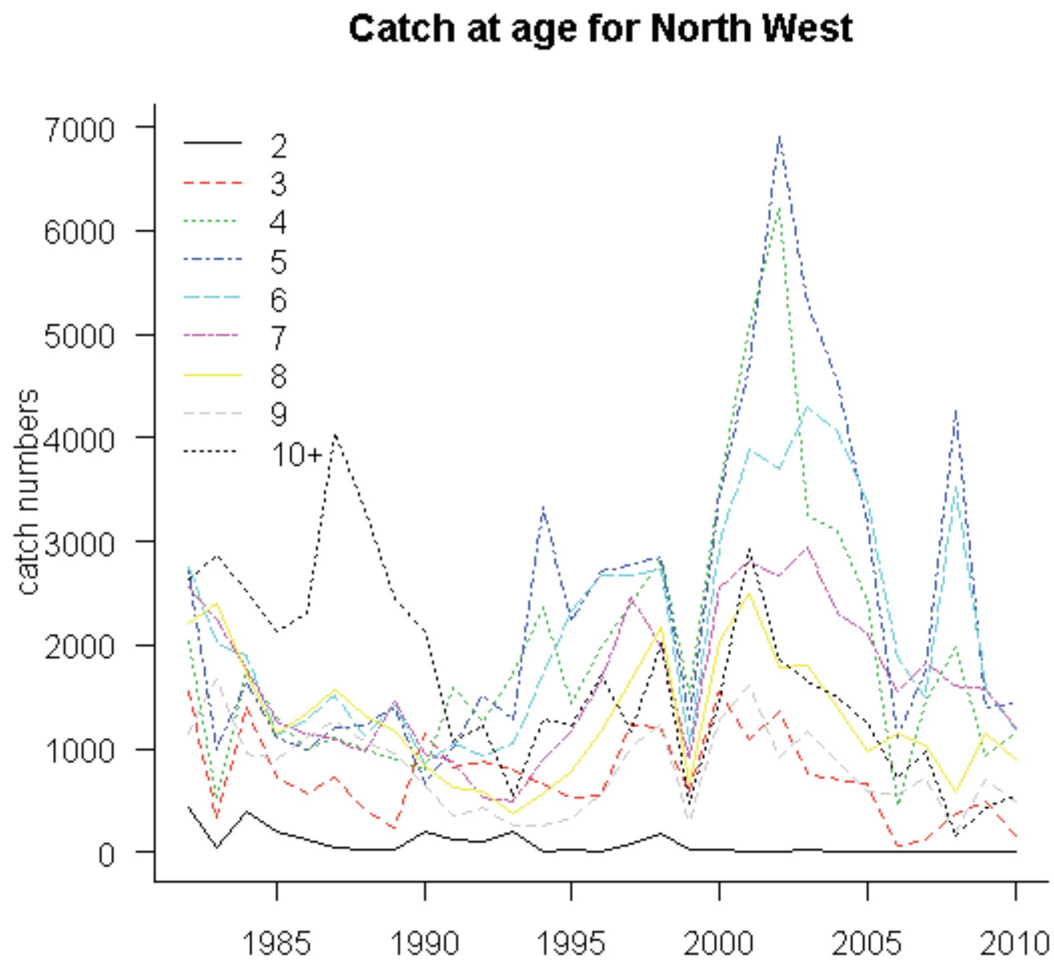


Figure 3.3.1: North West. Total catch-at-age numbers (in thousands).

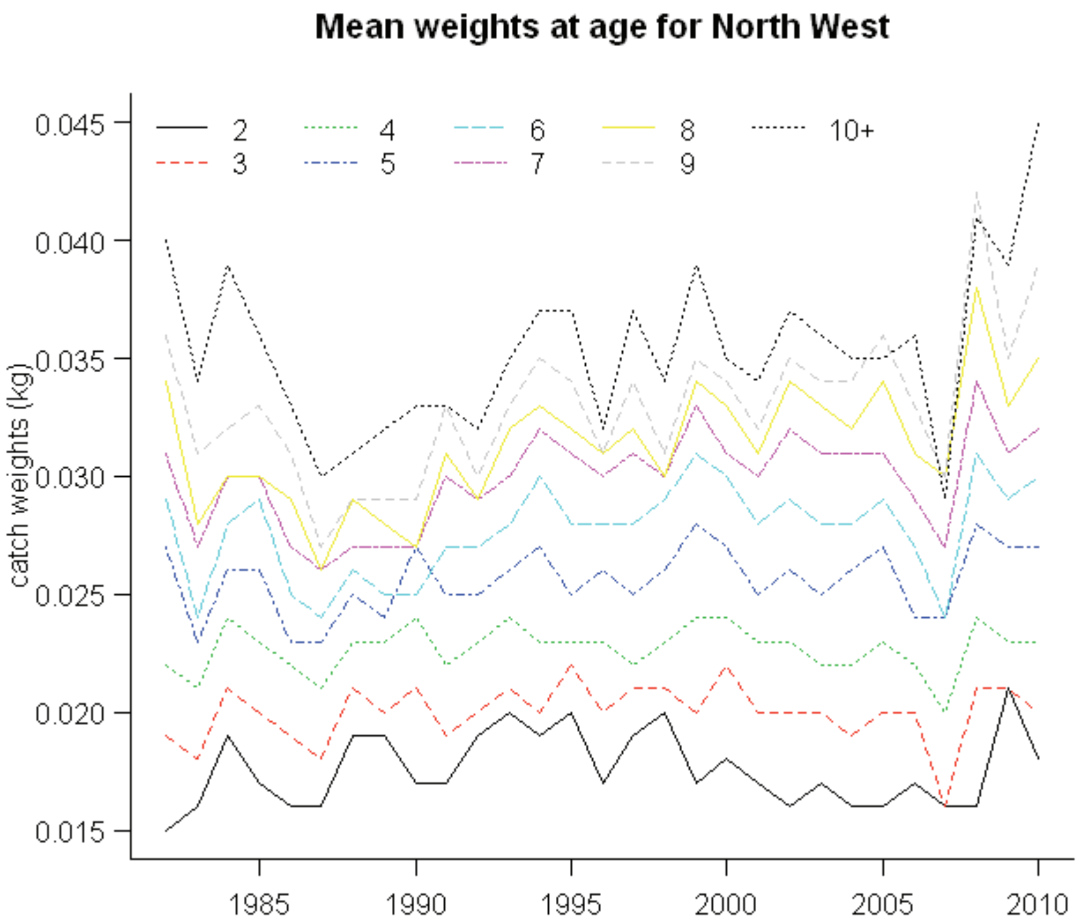


Figure 3.3.2: North West. Mean weights-at-age (kg) in total catch (also used for stock weights).

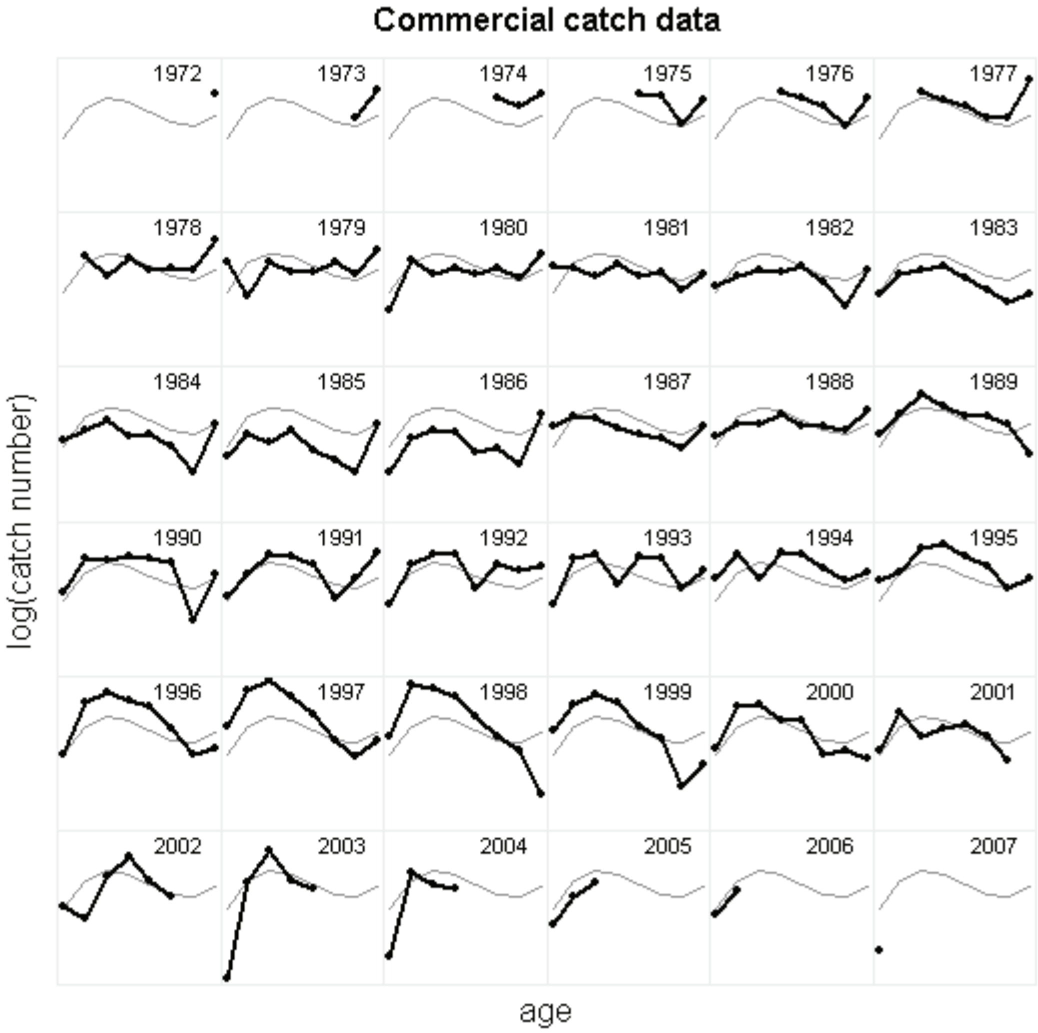
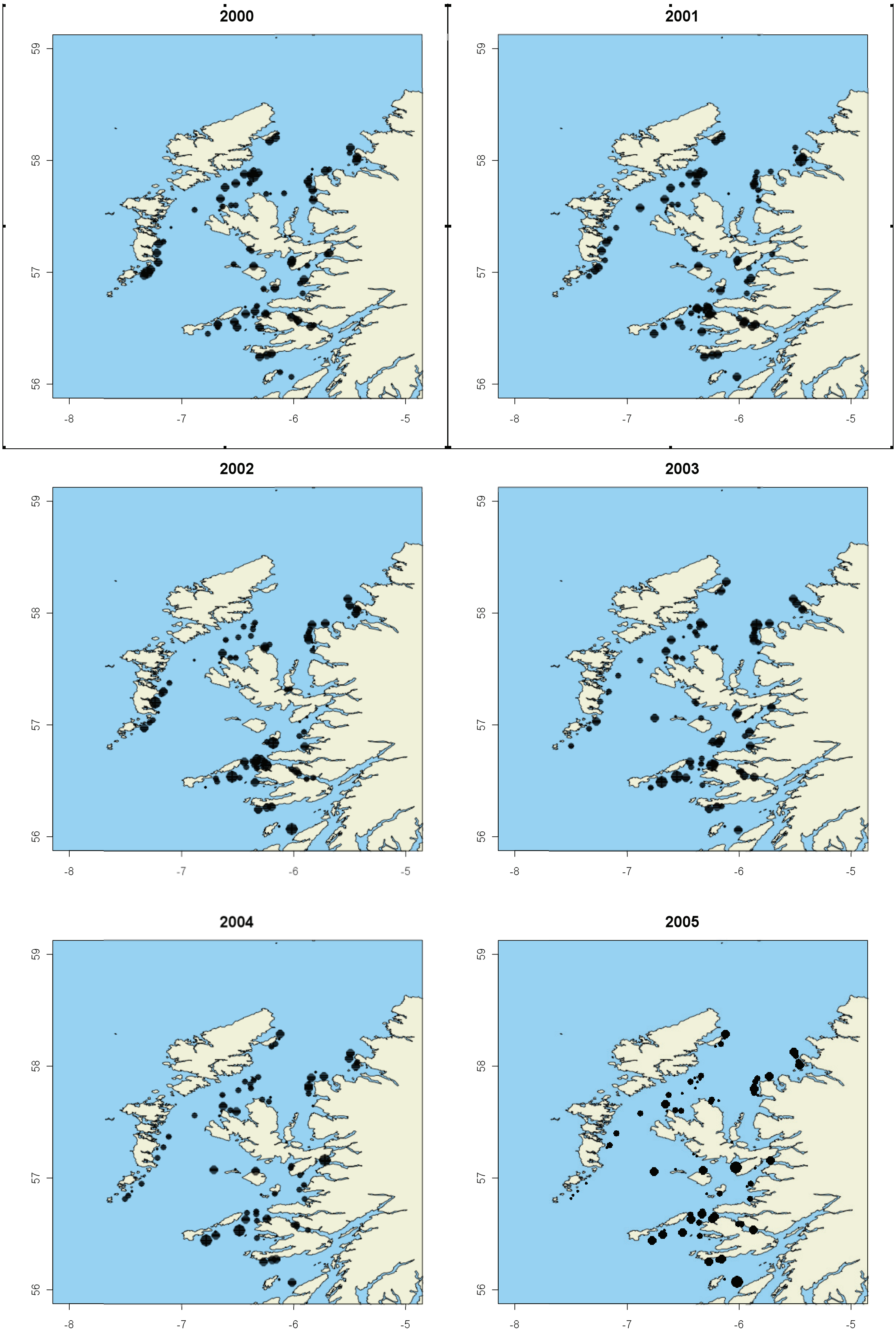


Figure 3.3.3: North West. Catch curves from commercial data (ages 3 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.


2000
2001
2002
2003
2004
2005
59
58
57
56
-8
-7
-6
-5

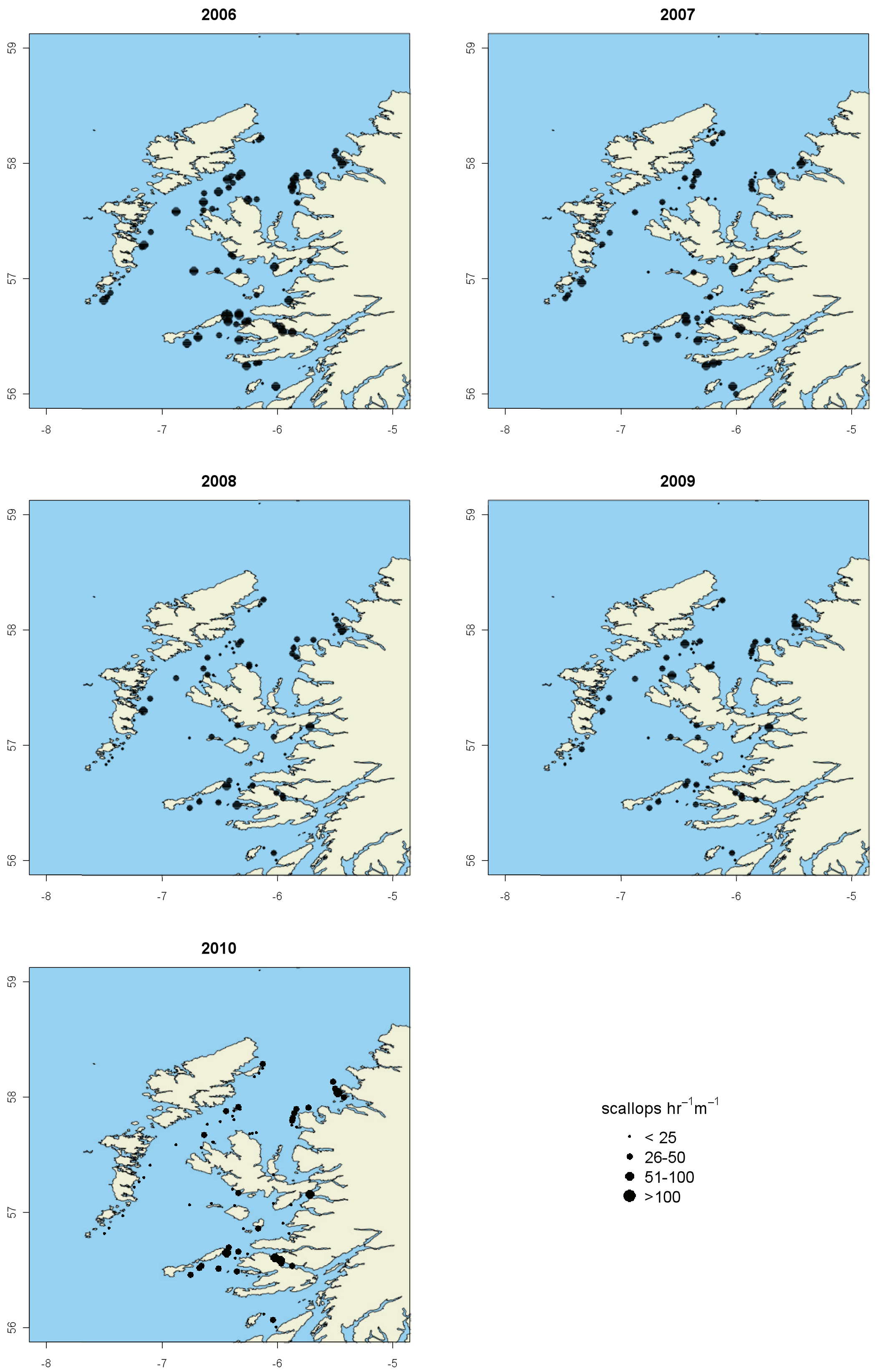


Figure 3.3.4: North West. Distribution of dredge survey catch rates (2000-2010).

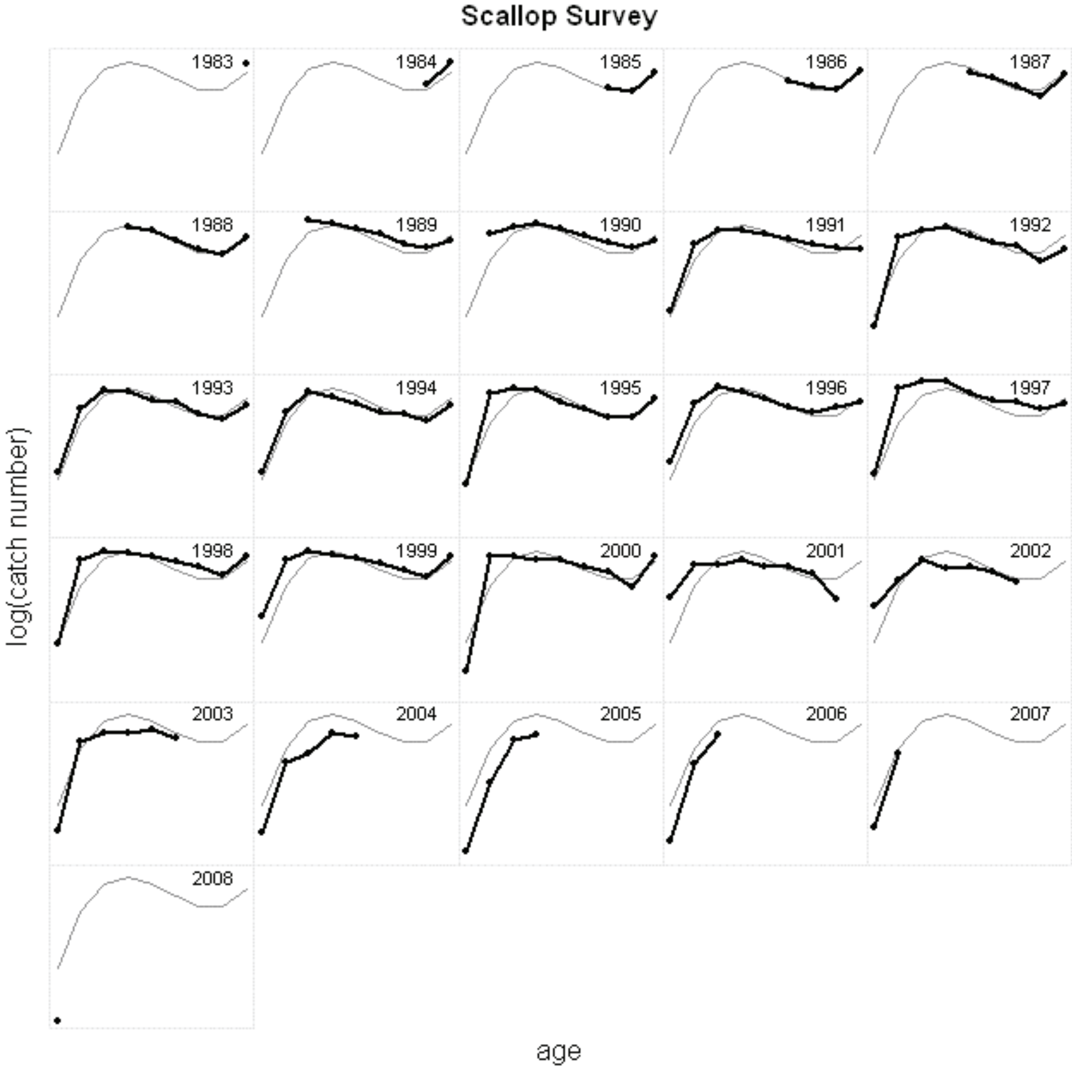


Figure 3.3.5: North West. Catch curves from survey data (ages 2 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.

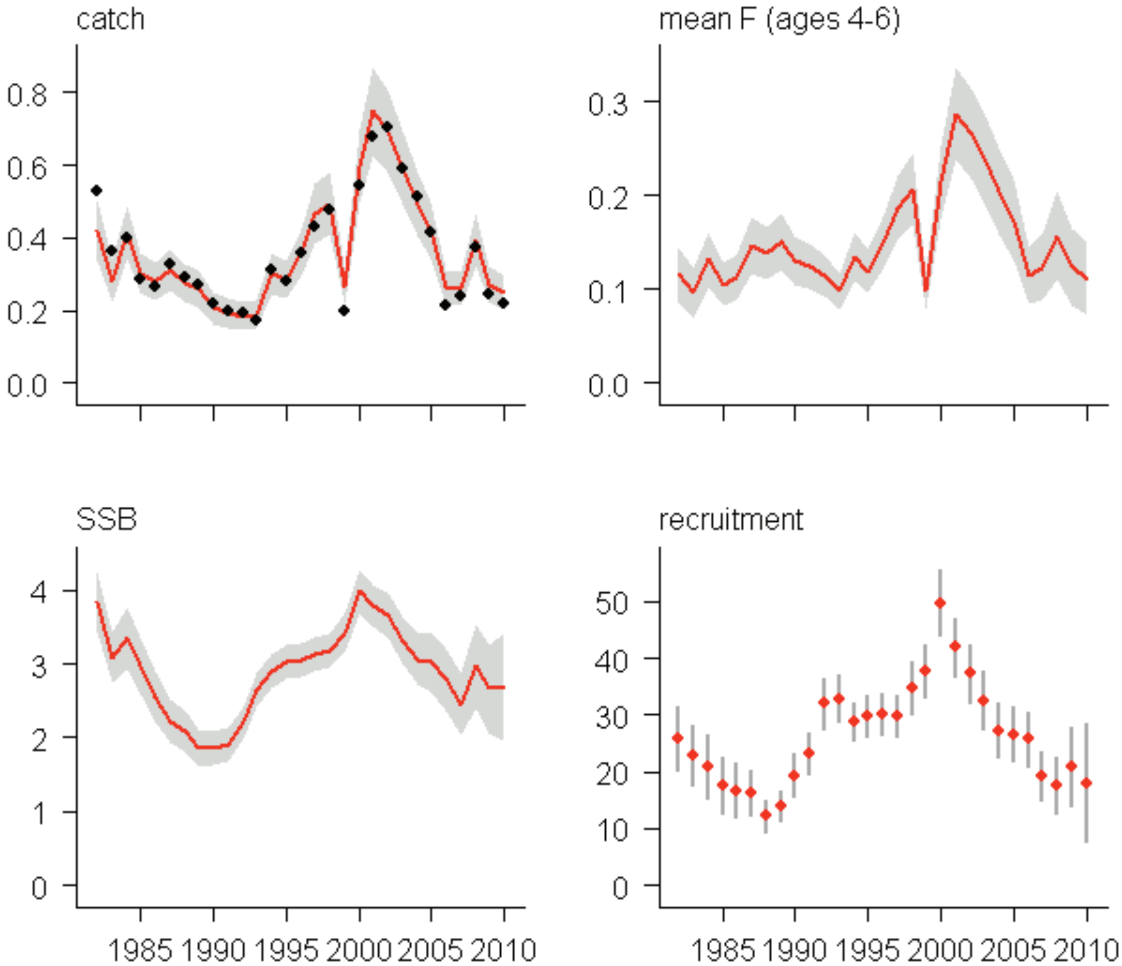


Figure 3.3.6: North West. TSA stock summaries from the final run. Catch and SSB are in terms of muscle weight (thousand tonnes) and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals.

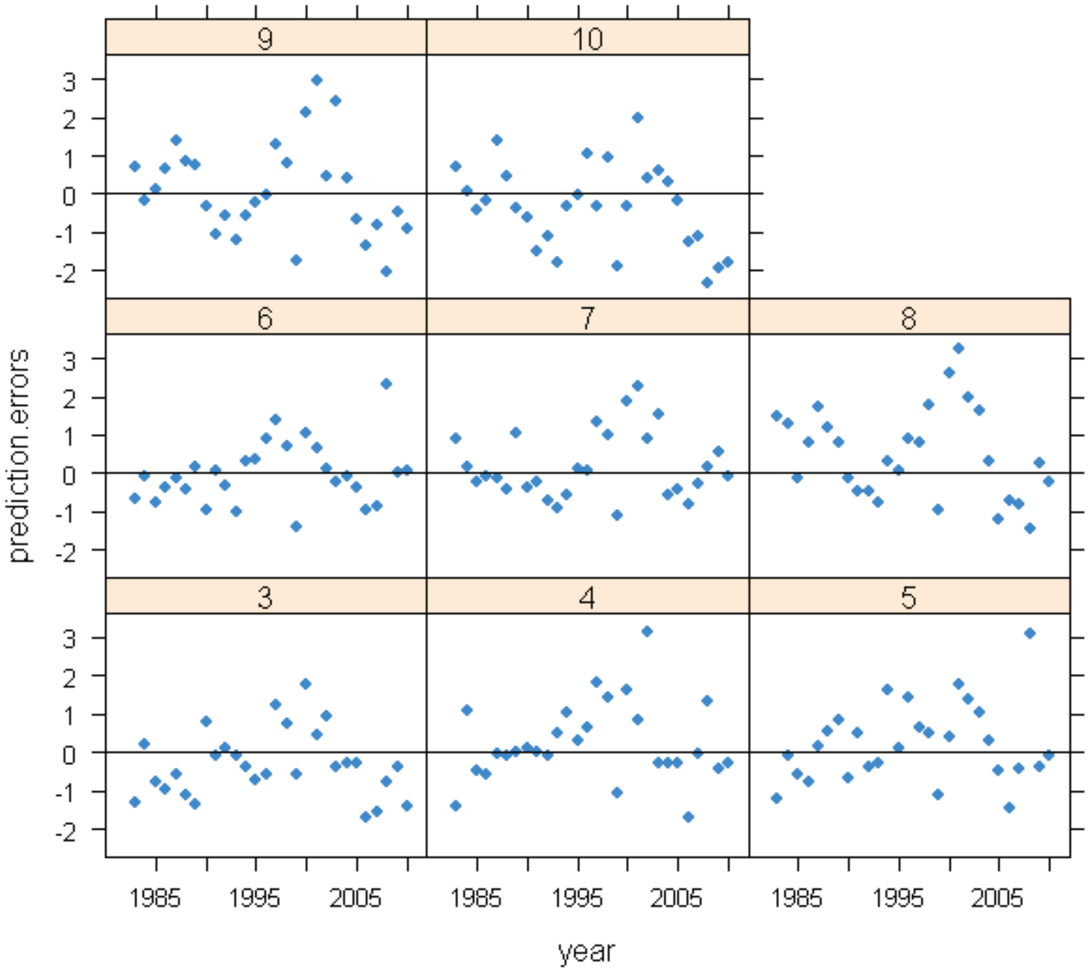


Figure 3.3.7: North West. Standardised catch prediction errors by age from the final TSA run.

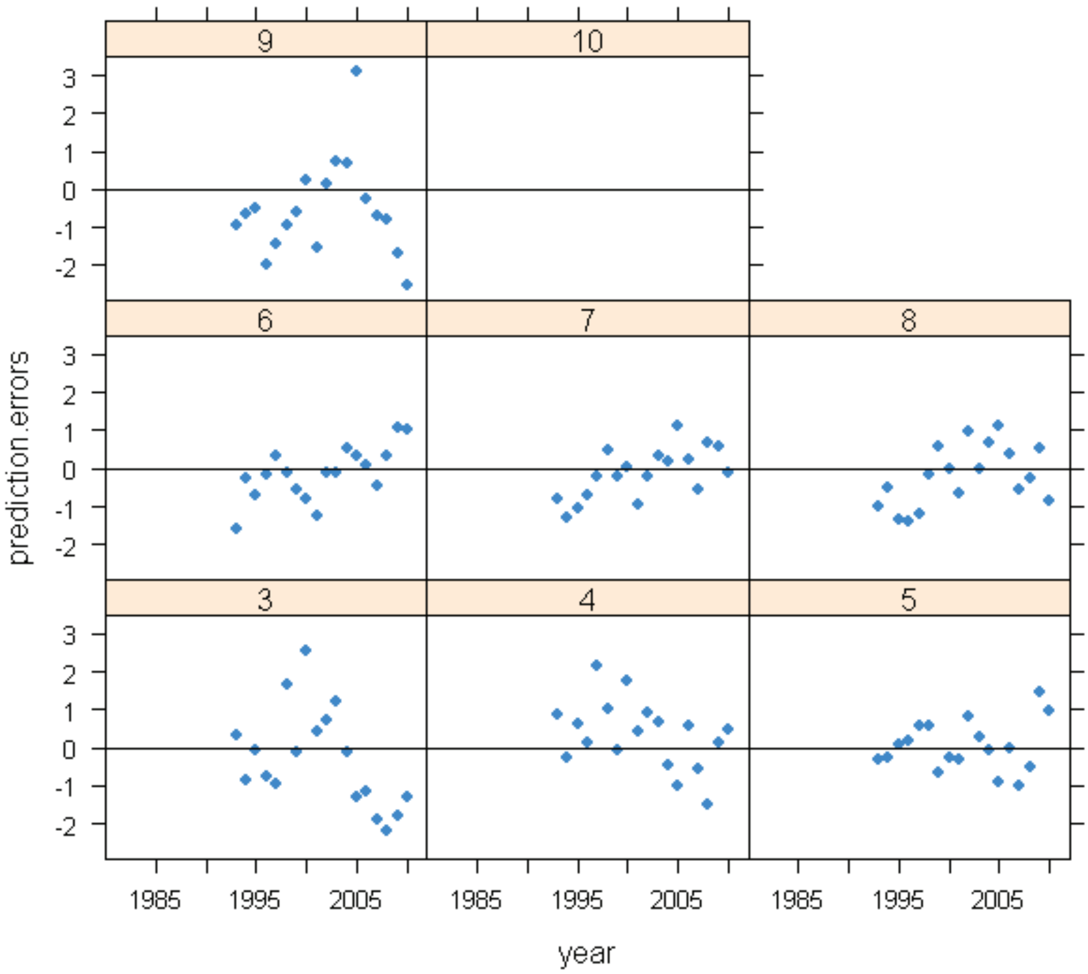


Figure 3.3.8: North West. Standardised survey prediction errors by age from the final TSA run.

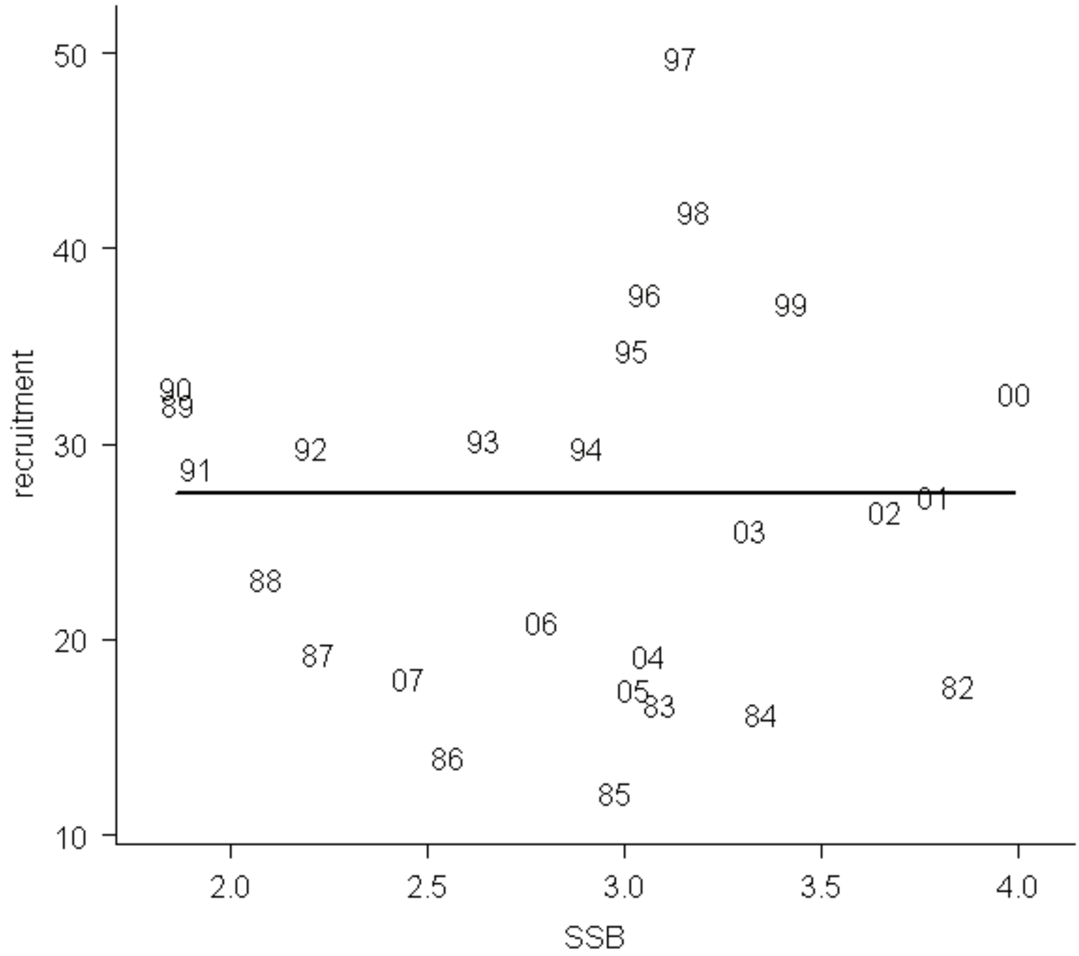


Figure 3.3.9: North West. Stock-recruit plot from the final TSA run. Recruitment is in millions (age 3) and SSB in thousand tonnes of muscle weight.. Values are labelled with year class.

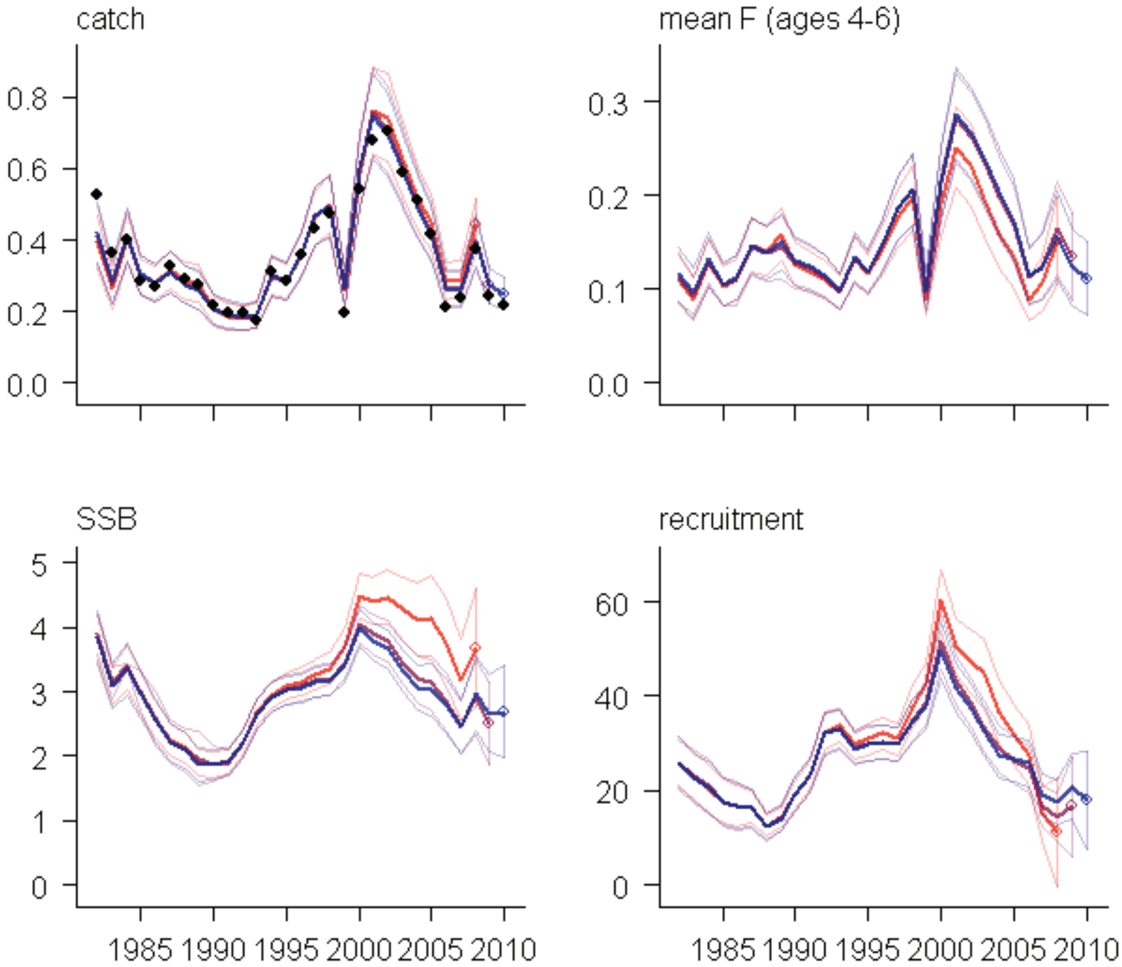


Figure 3.3.10: North West. Estimates of Catch, Mean $F_{4\text{-}6}$, SSB and Recruitment with 95% confidence intervals (pale lines) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment in millions. Blue line: data to 2010, maroon line: data to 2009 and red line: data to 2008.

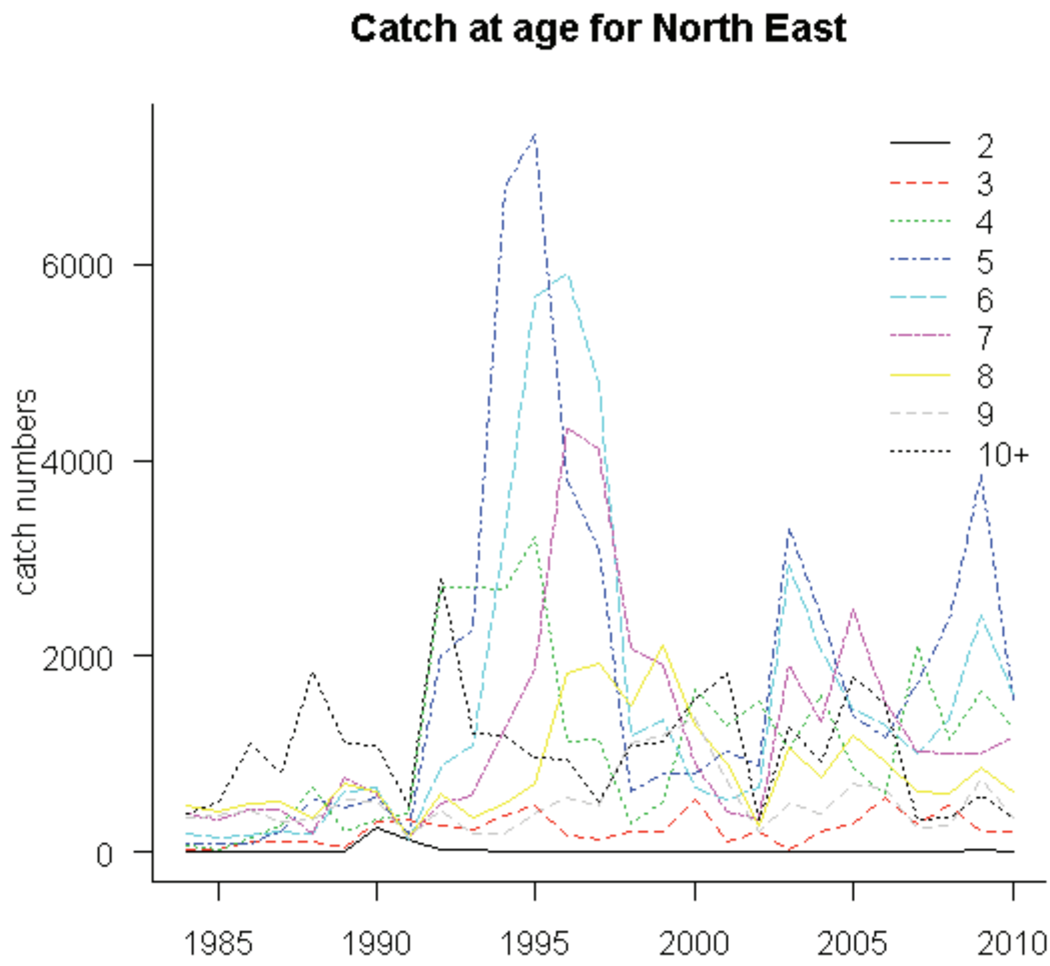


Figure 3.6.1: North East. Total catch-at-age numbers (in thousands).

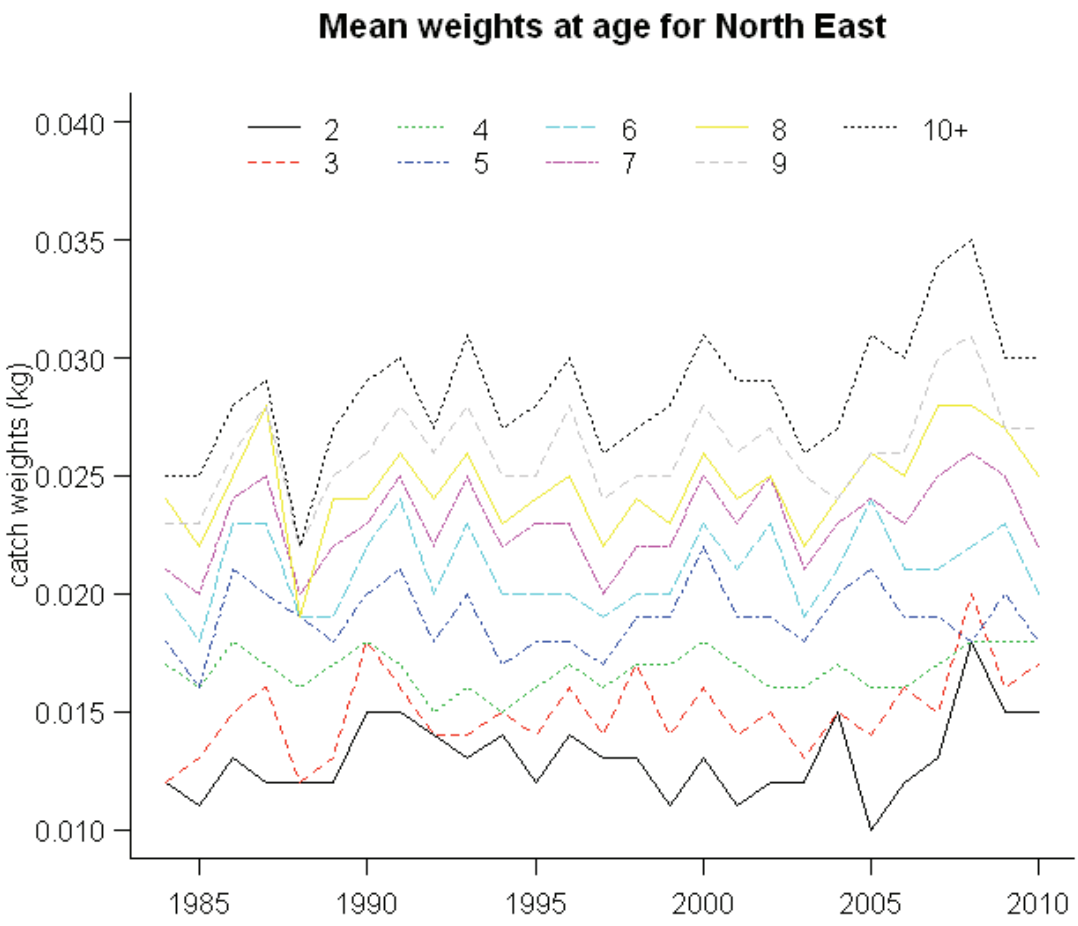


Figure 3.6.2: North East. Mean weights-at-age (kg) in total catch (also used for stock weights).

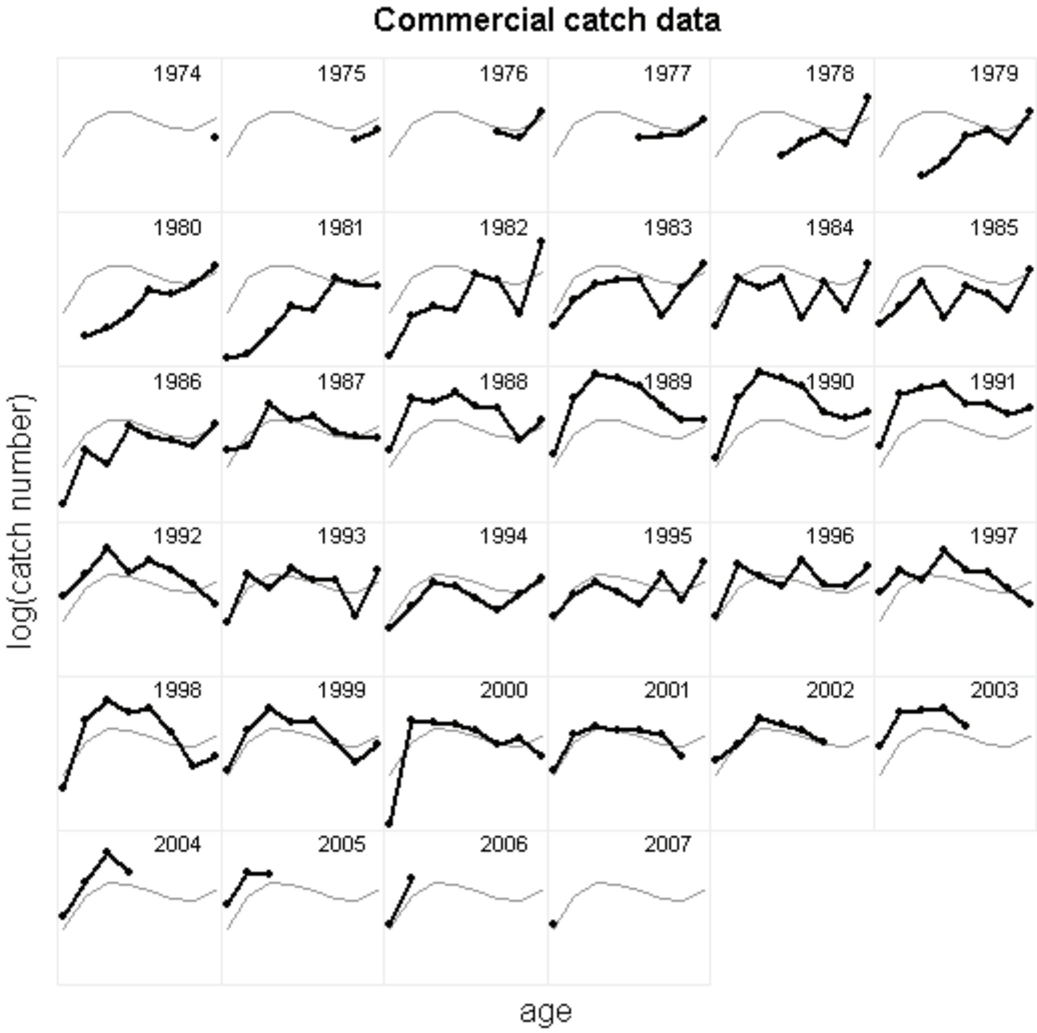
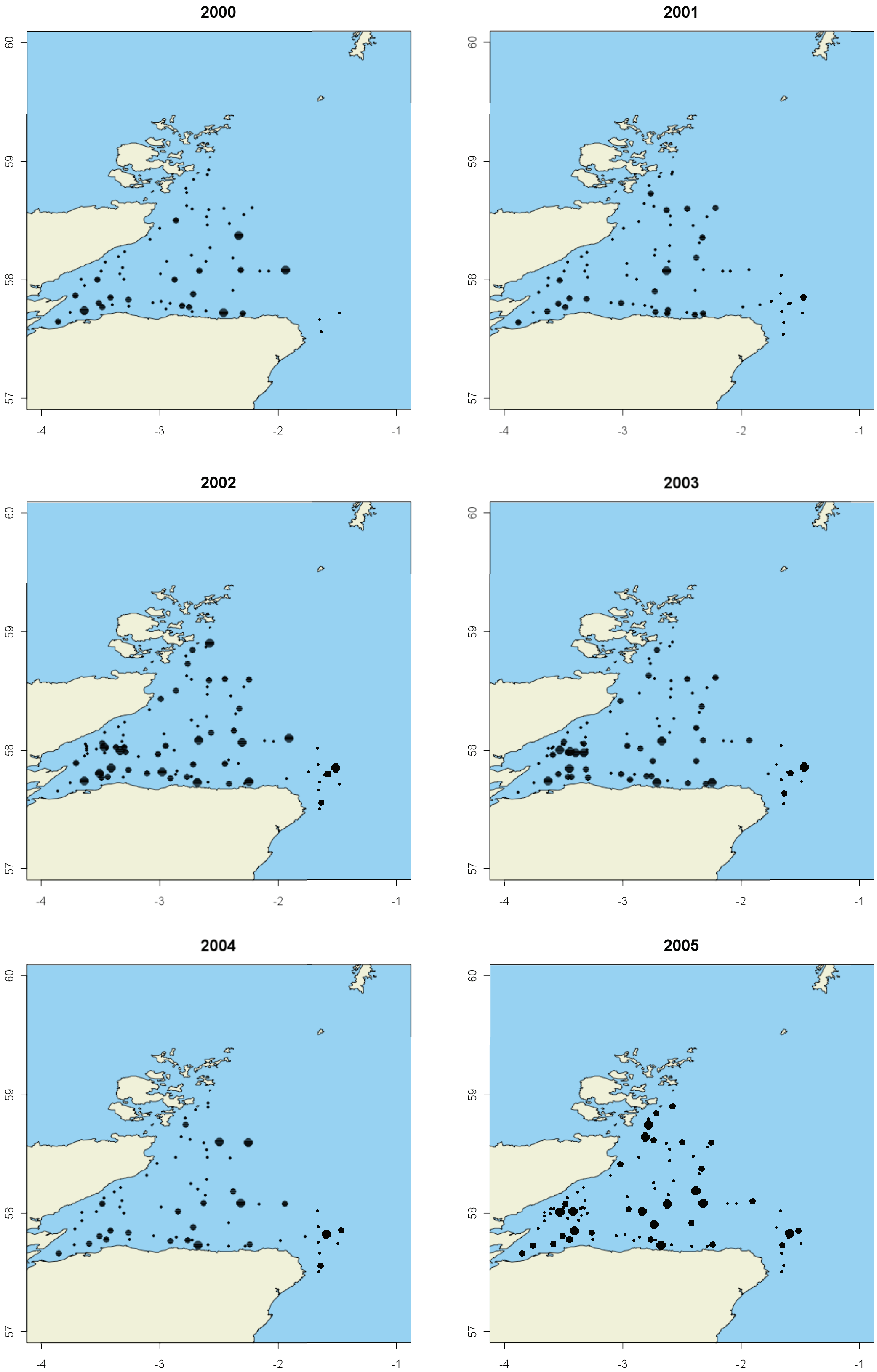


Figure 3.6.3: North East. Catch curves from commercial data (ages 3 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.


2000
2001
2002
2003
2004
2005
60
59
58
57
-4
-3
-2
-1

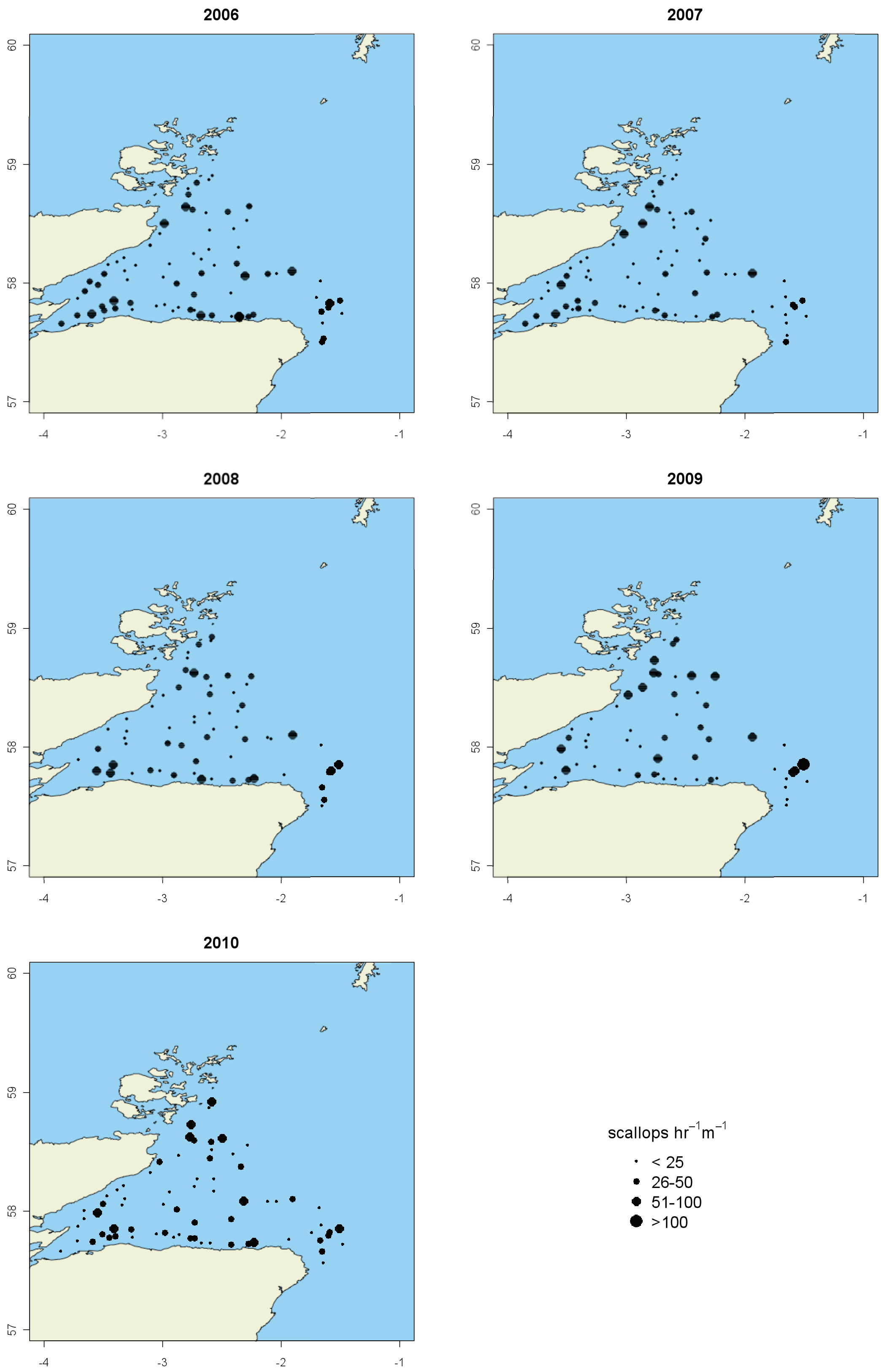


Figure 3.6.4: North East. Distribution of dredge survey catch rates (2000-2010).

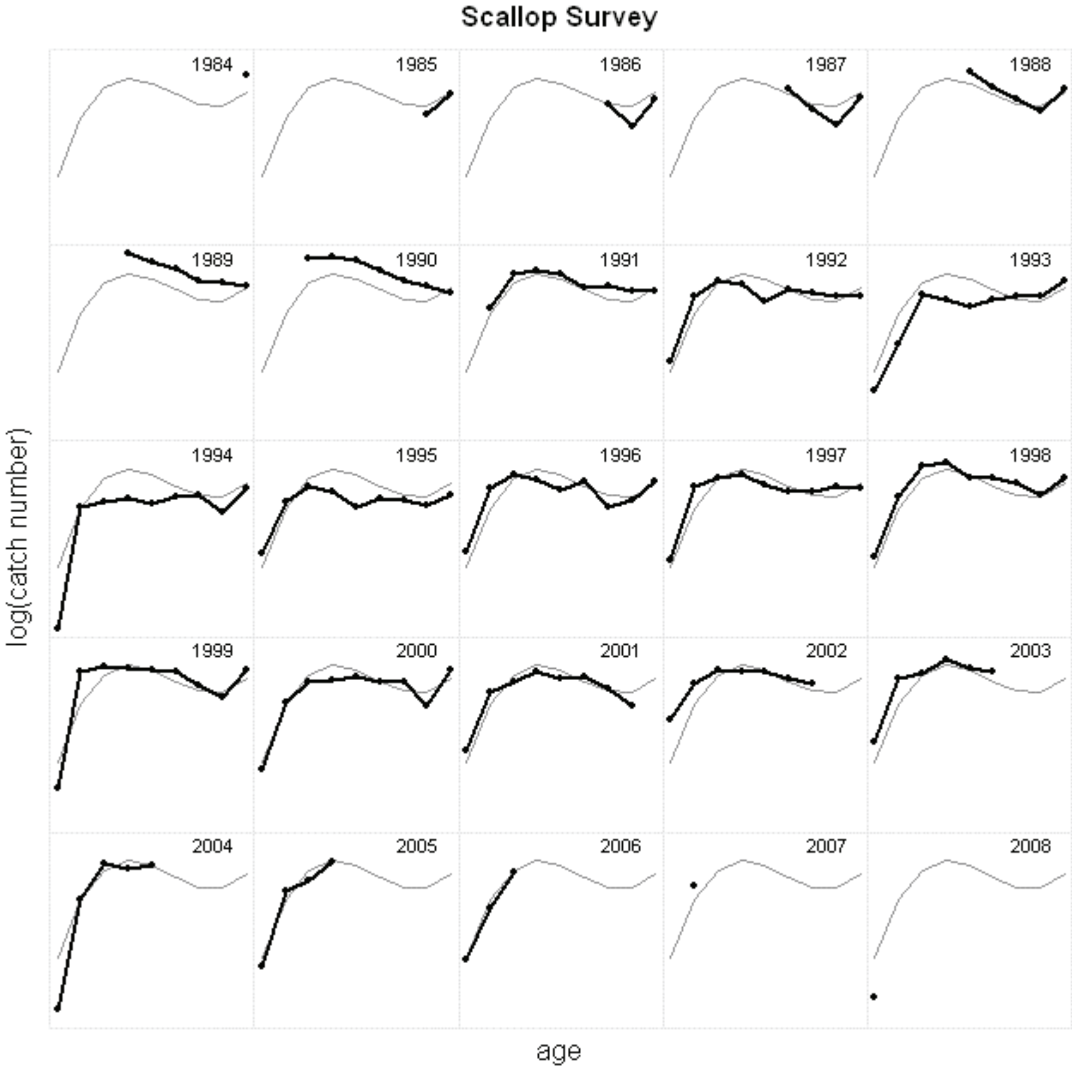


Figure 3.6.5: North East. Catch curves from survey data (ages 2 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.

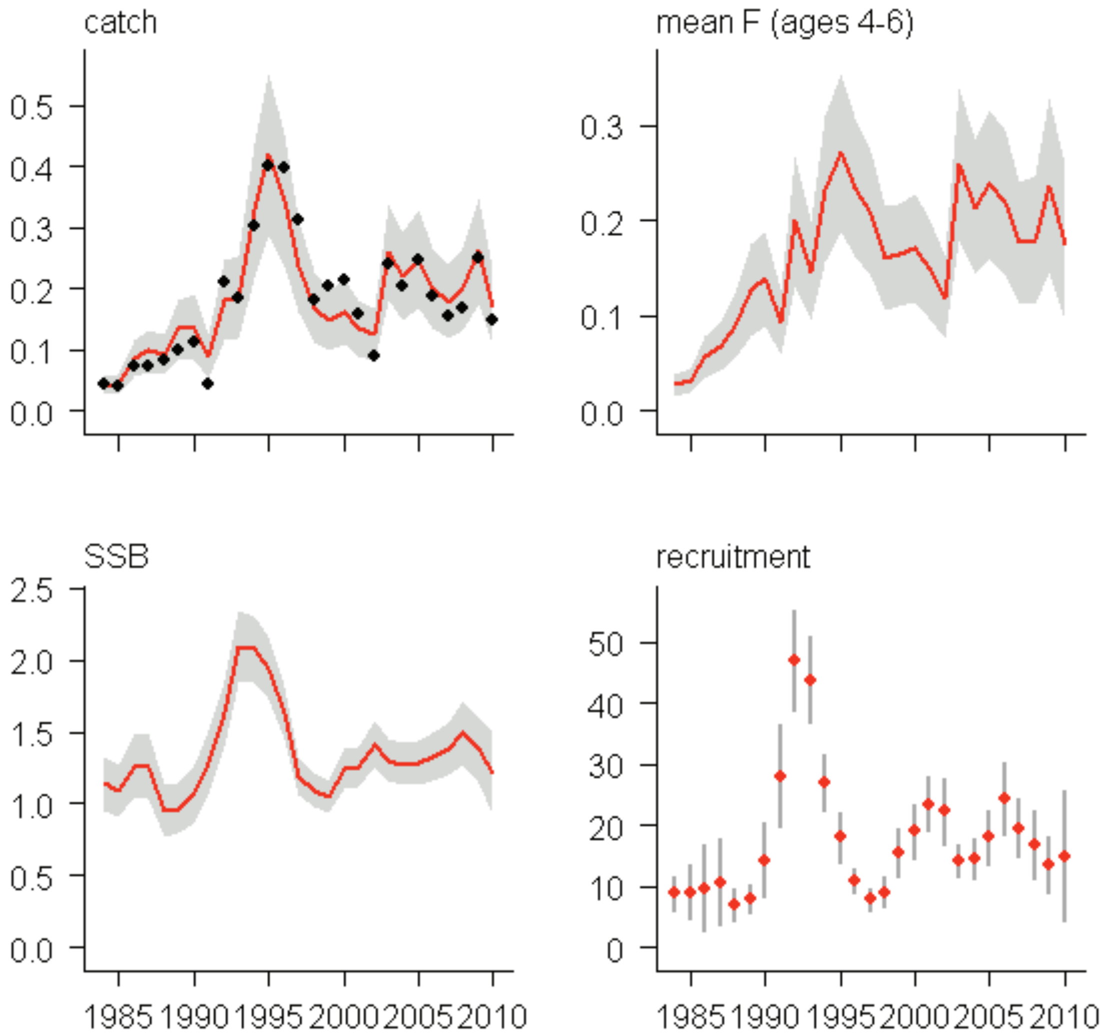


Figure 3.6.6: North East. TSA stock summaries from the final TSA run. Catch and SSB are in thousand tonnes and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals.

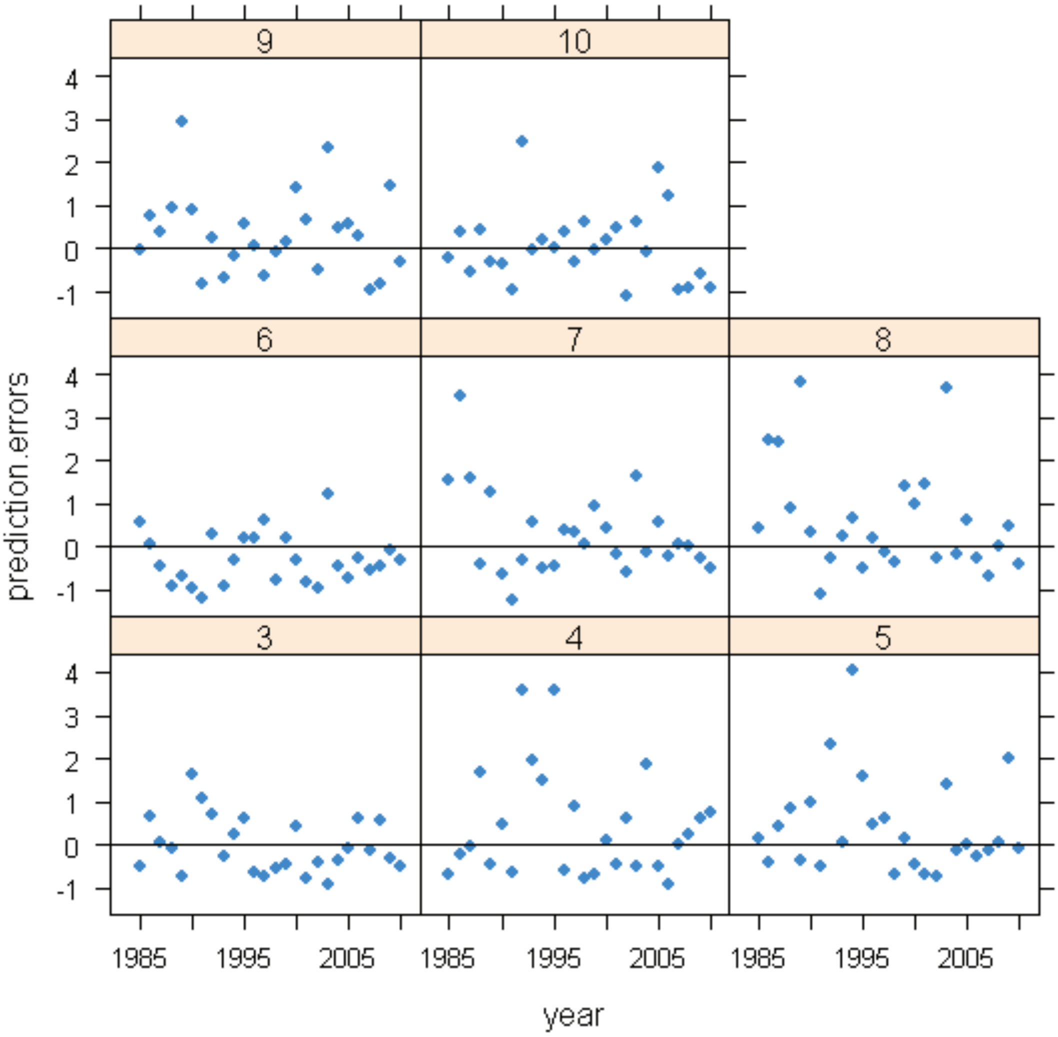


Figure 3.6.7: North East. Standardised catch prediction errors by age from the final TSA run.

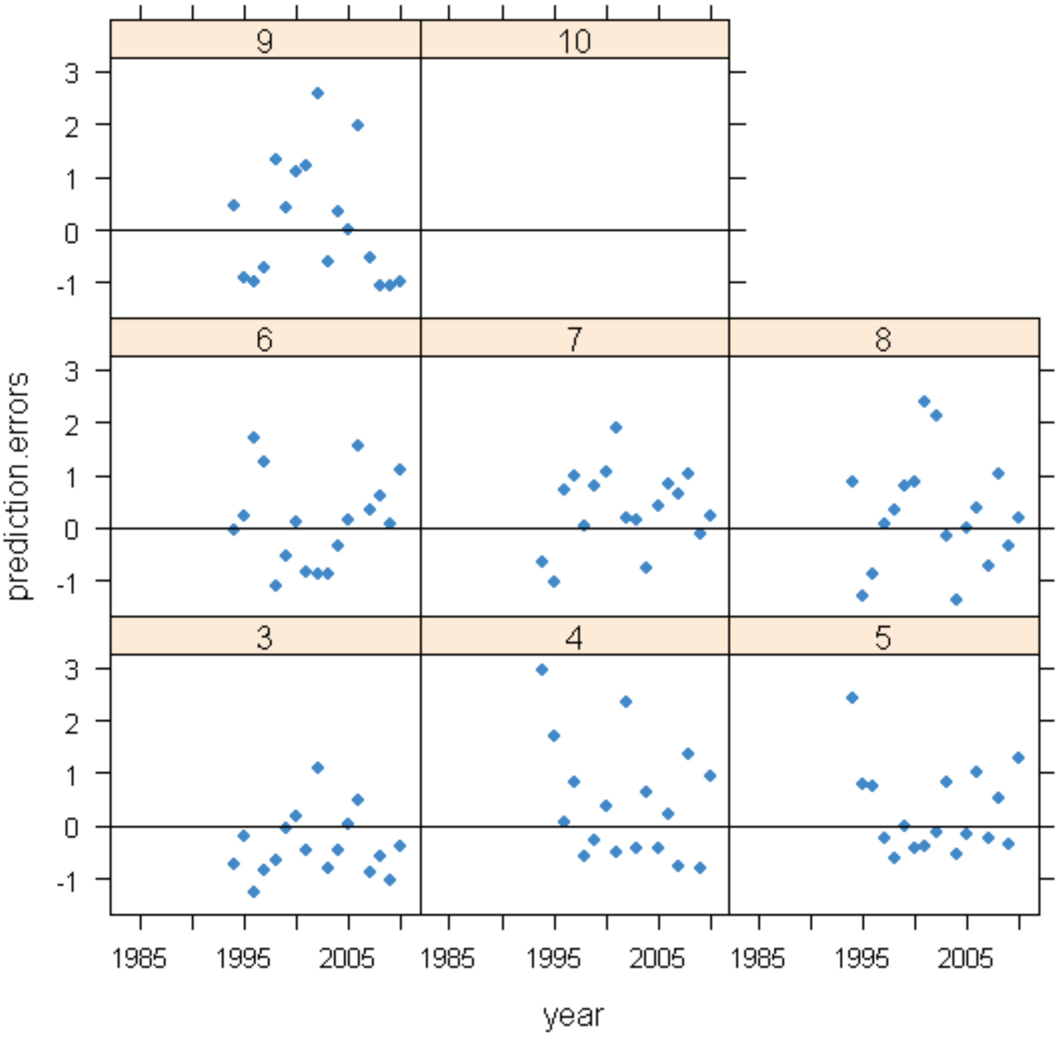


Figure 3.6.8: North East. Standardised survey prediction errors by age from the final TSA run.

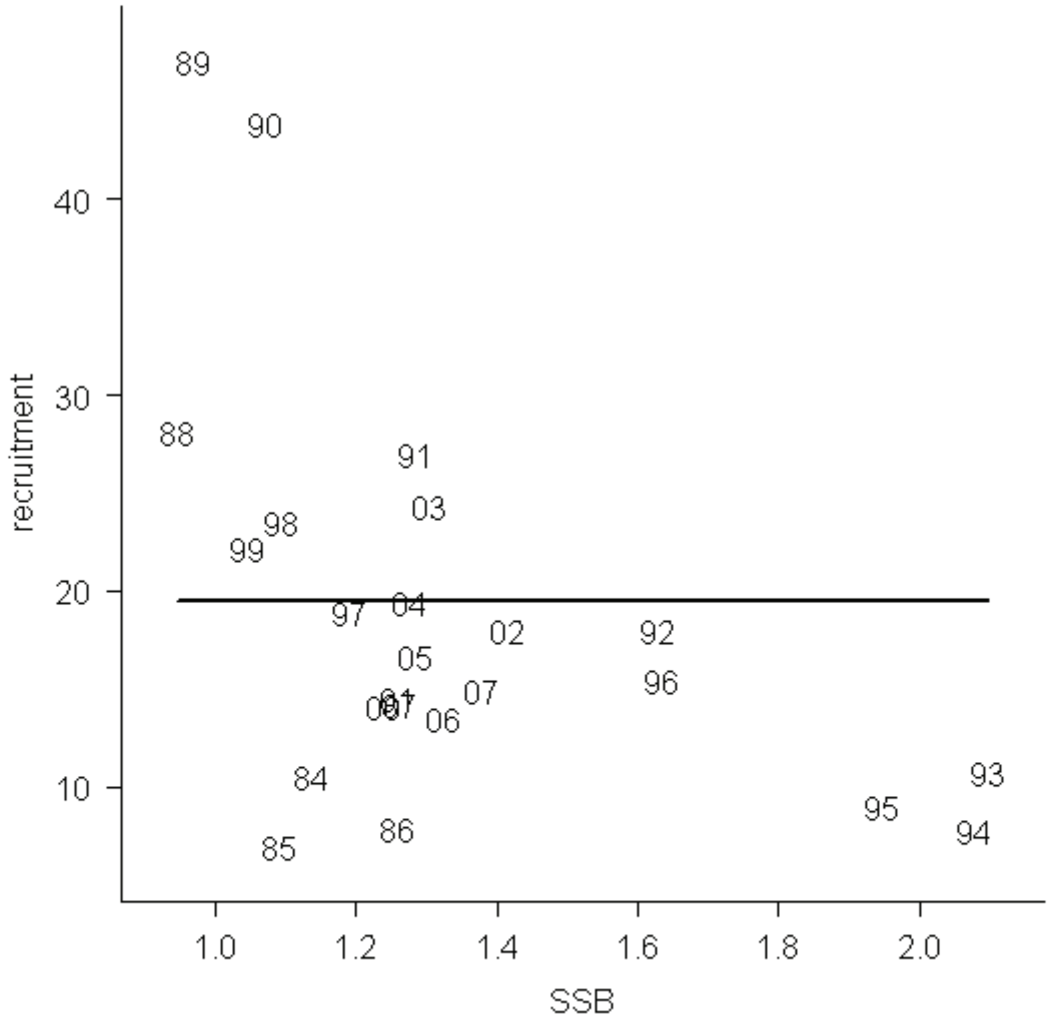


Figure 3.6.9: North East. Stock-recruit plot from the final TSA run. Recruitment (age 3) is in millions and SSB in thousand tonnes of muscle weight. Values are labelled with year class.

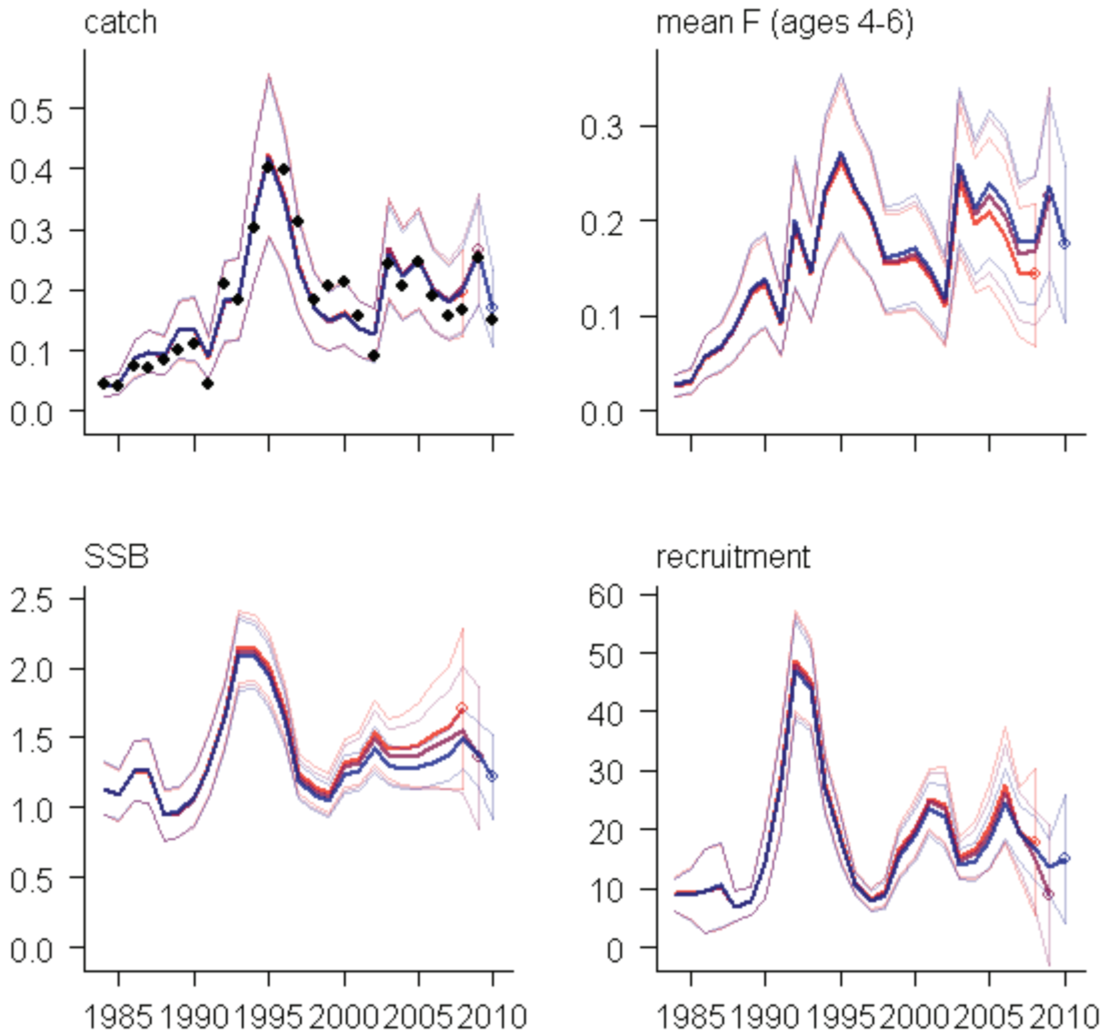


Figure 3.6.10: North East. Estimates of Catch, Mean $F_{4\text{-}6}$, SSB and Recruitment with 95% confidence intervals (pale lines) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment in millions. Blue line: data to 2010, maroon line: data to 2009 and red line: data to 2008.

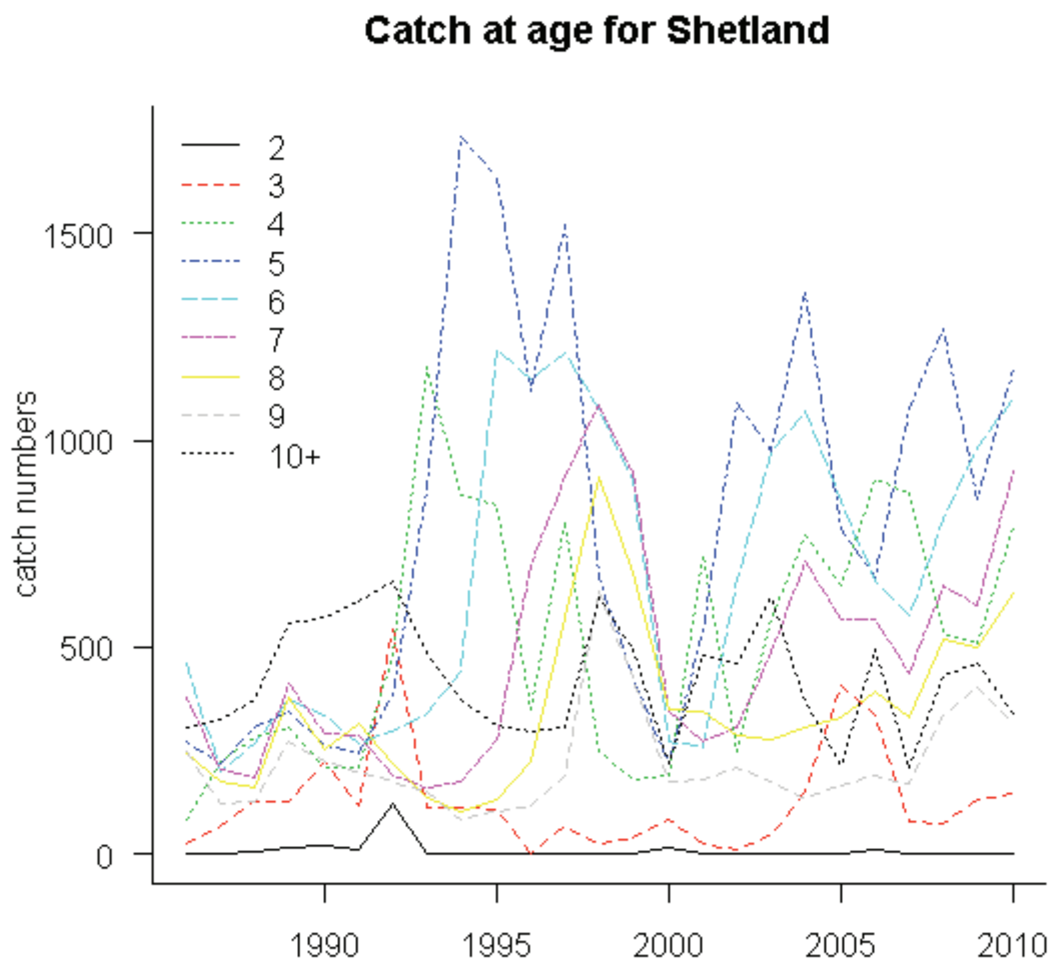


Figure 3.7.1: Shetland. Total catch-at-age numbers (in thousands).

Figure 3.7.2: Shetland. Mean weights-at-age (kg) in total catch (also used for stock weights).

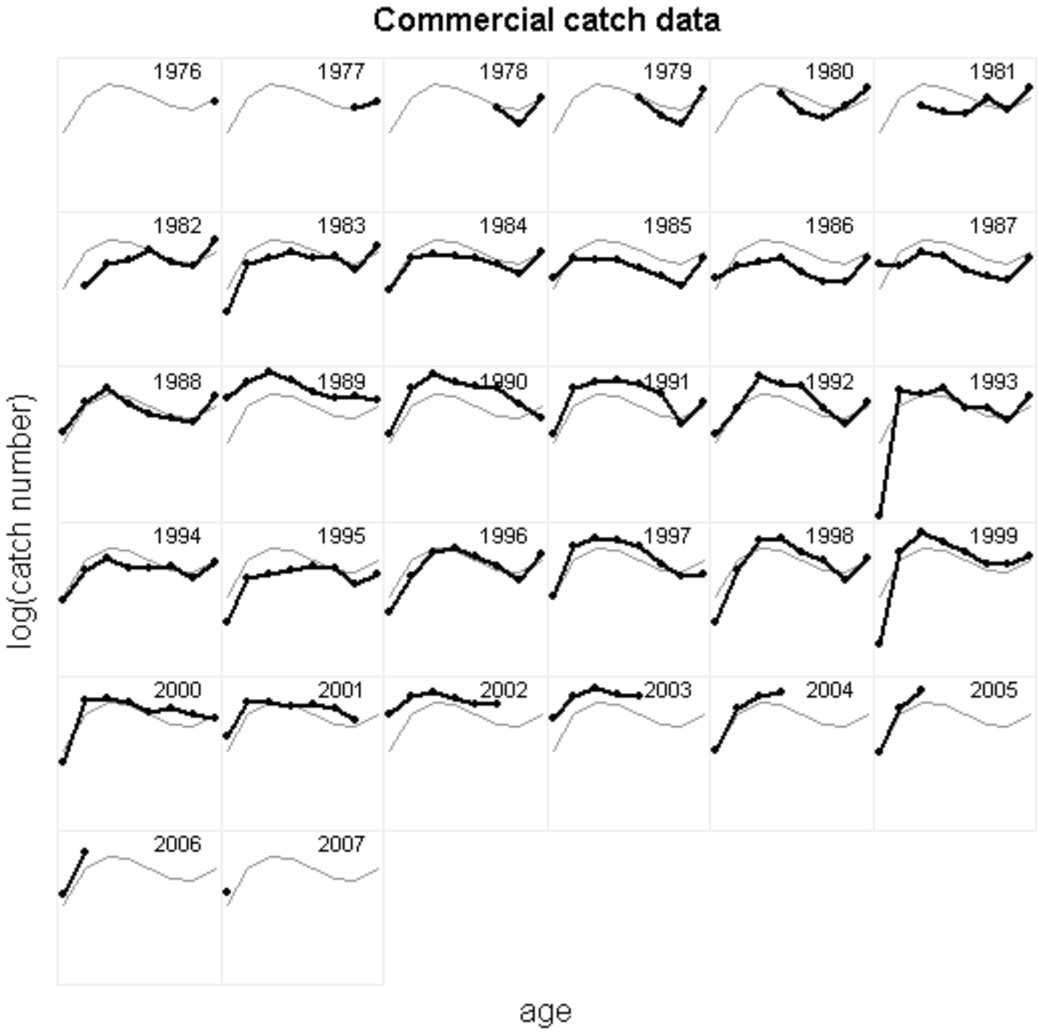


Figure 3.7.3: Shetland. Catch curves from commercial data (ages 3 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.

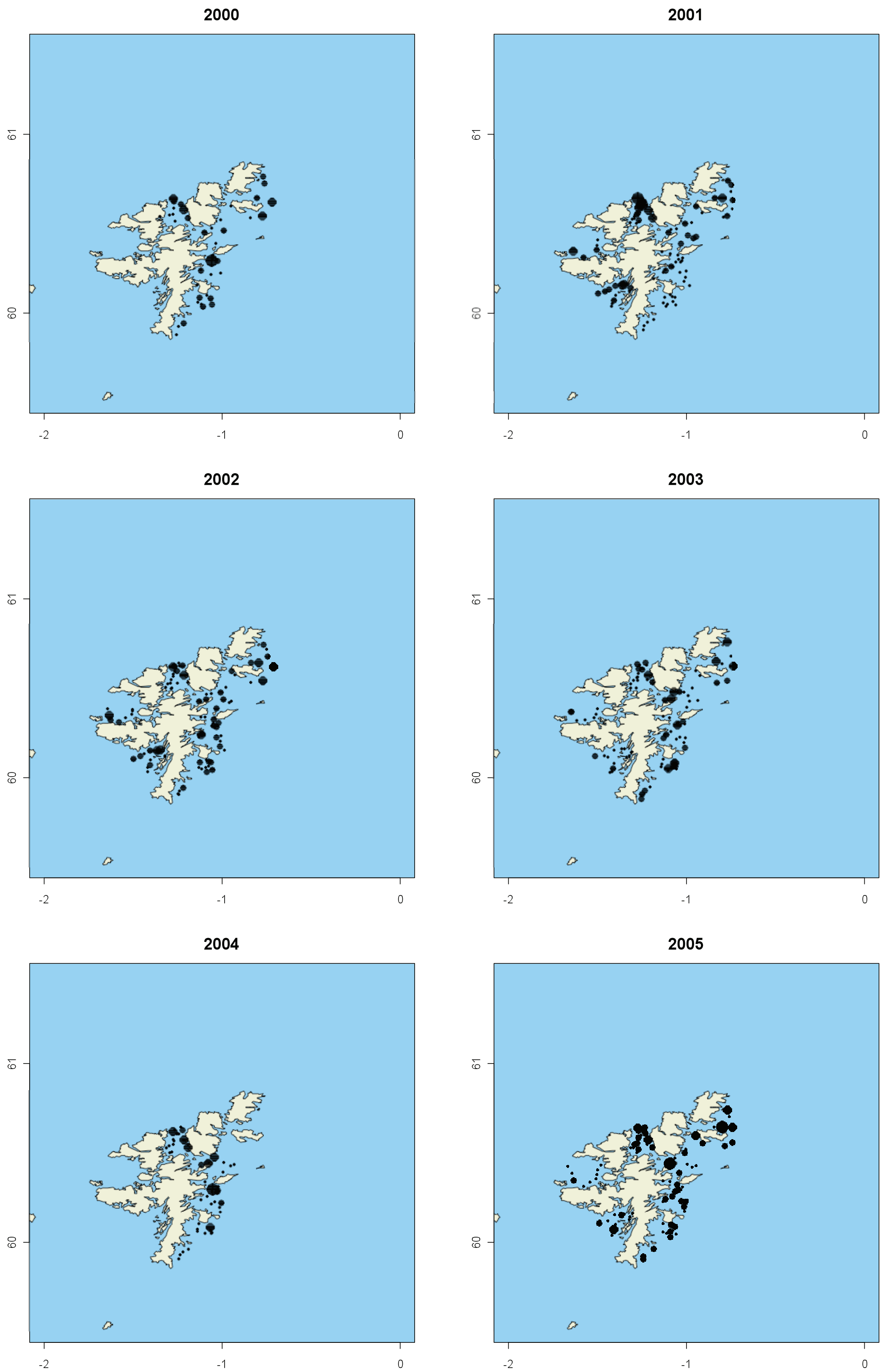

2000
2001
2002
2003
2004
2005
61
60
-2
-1
0

Figure 3.7.4: Shetland. Distribution of dredge survey catch rates (2000-2010).

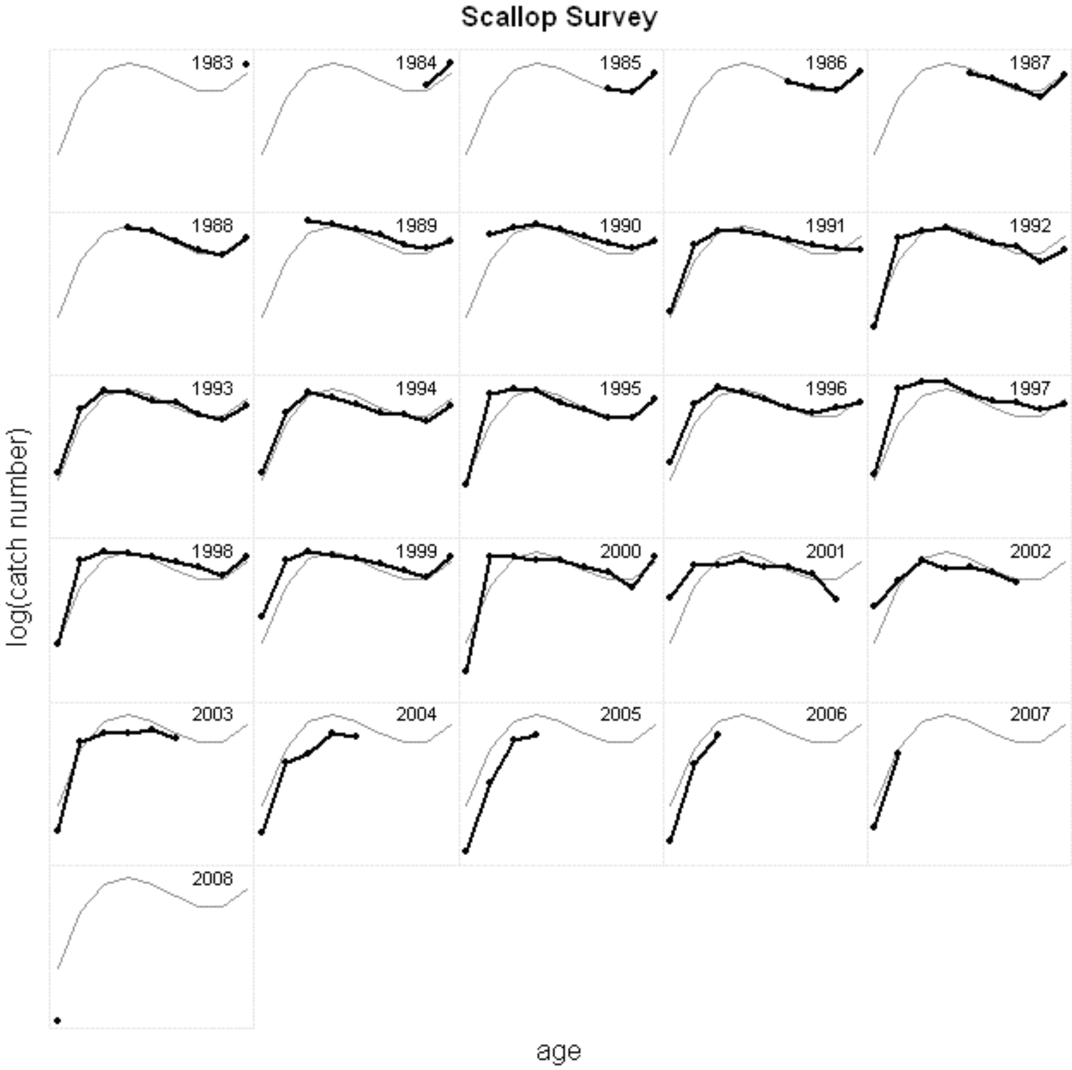
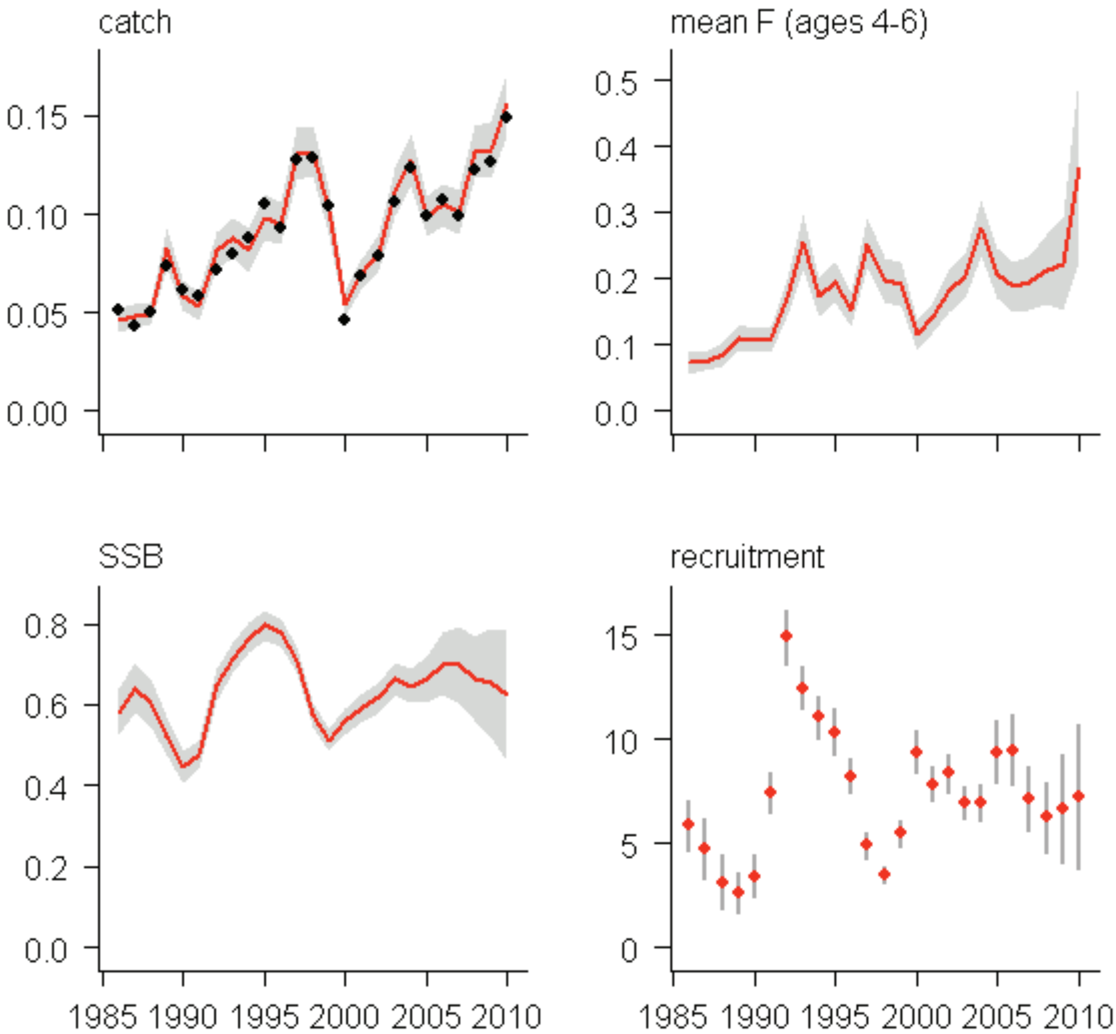


Figure 3.7.5: Shetland. Catch curves from survey data (ages 2 - 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.



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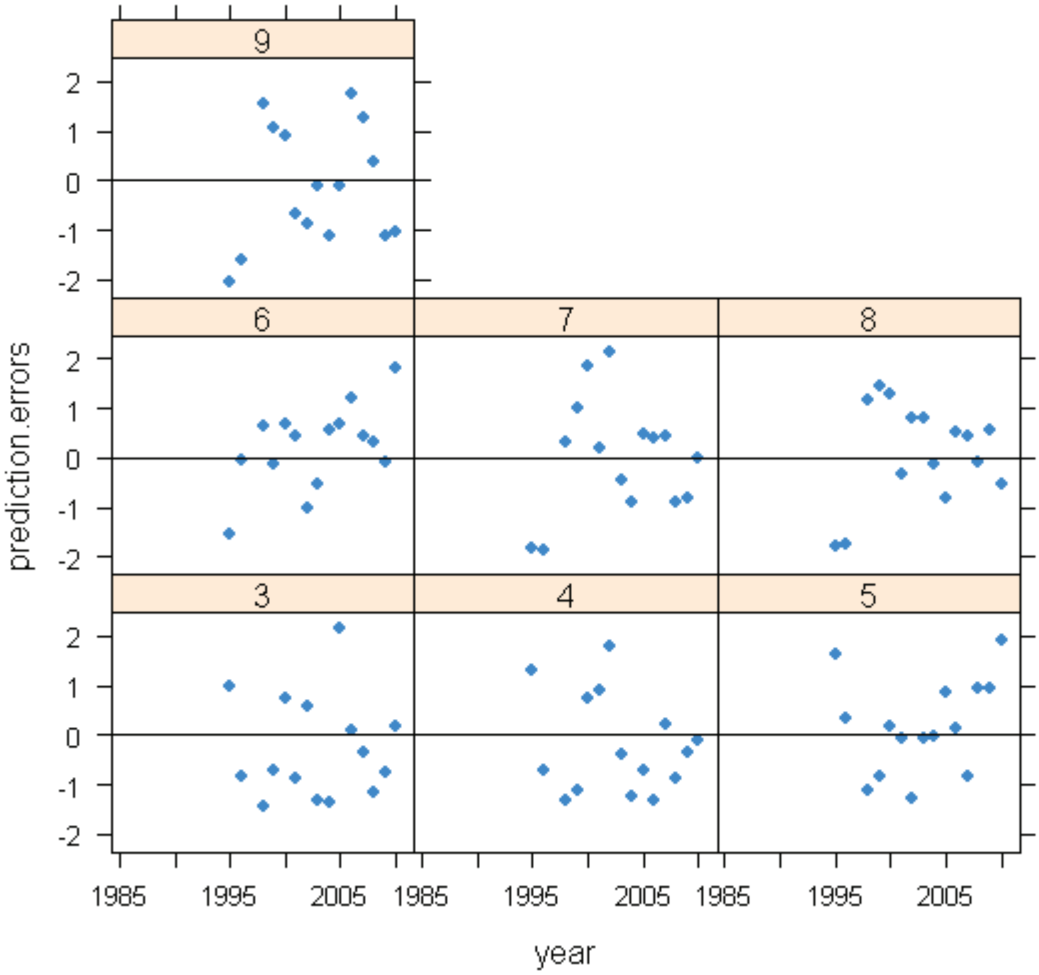


Figure 3.7.7: Shetland. Standardised catch prediction errors by age from the final TSA run.

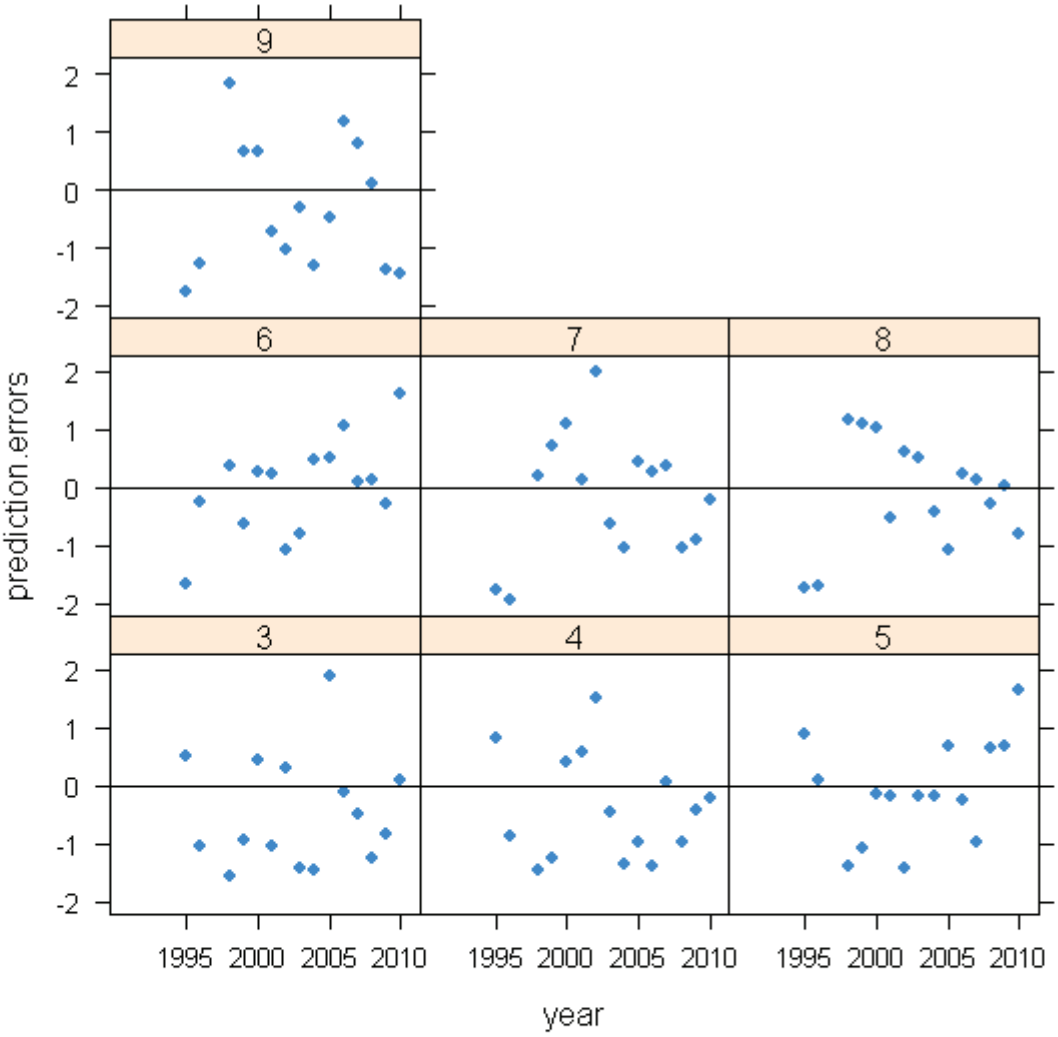
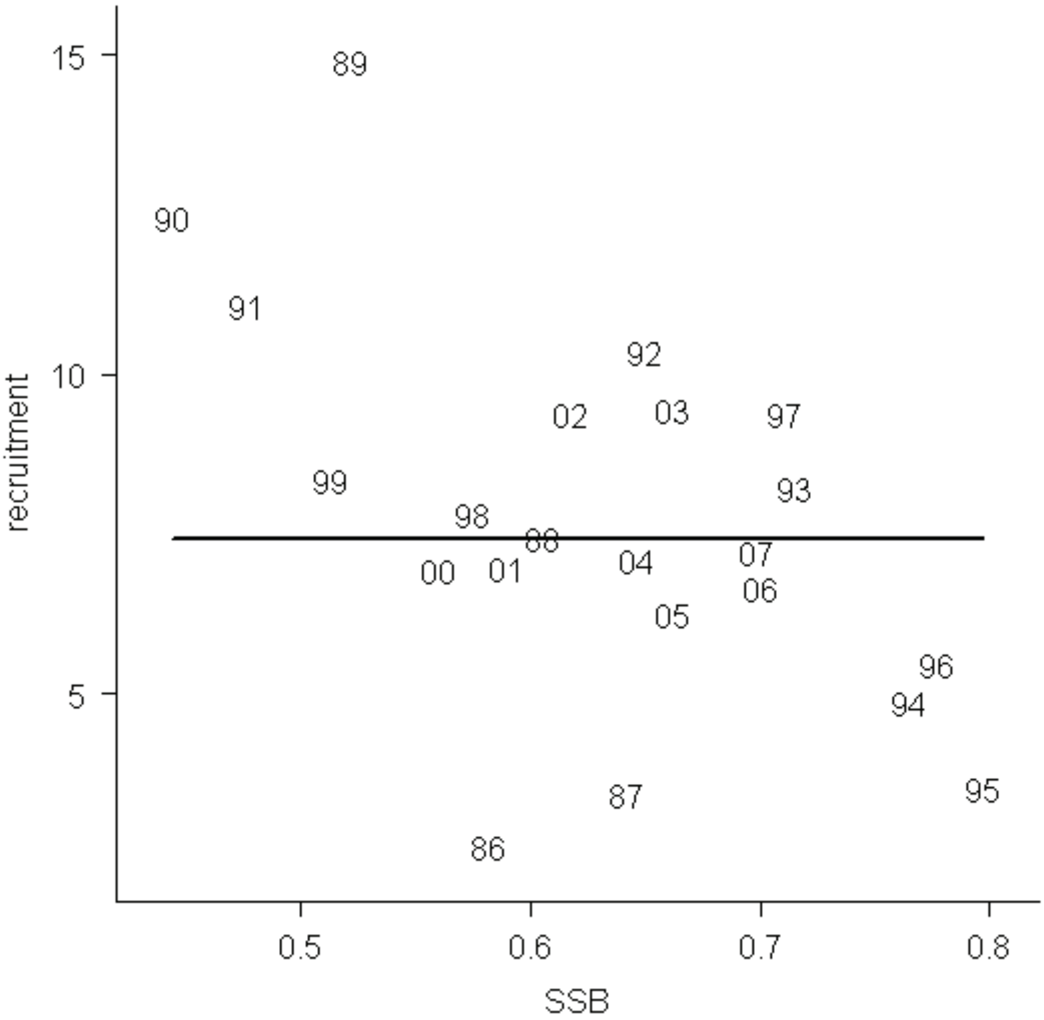


Figure 3.7.8: Shetland. Standardised survey prediction errors by age from the final TSA run.



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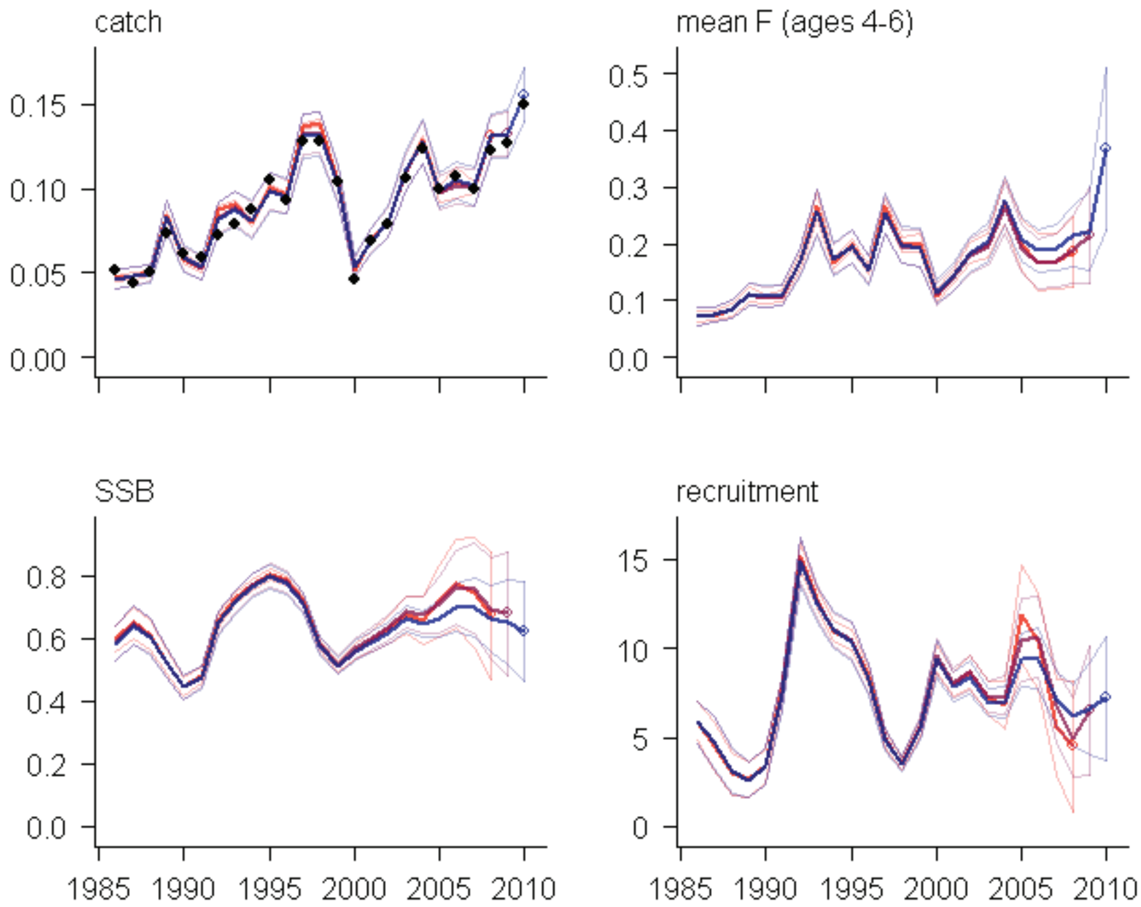

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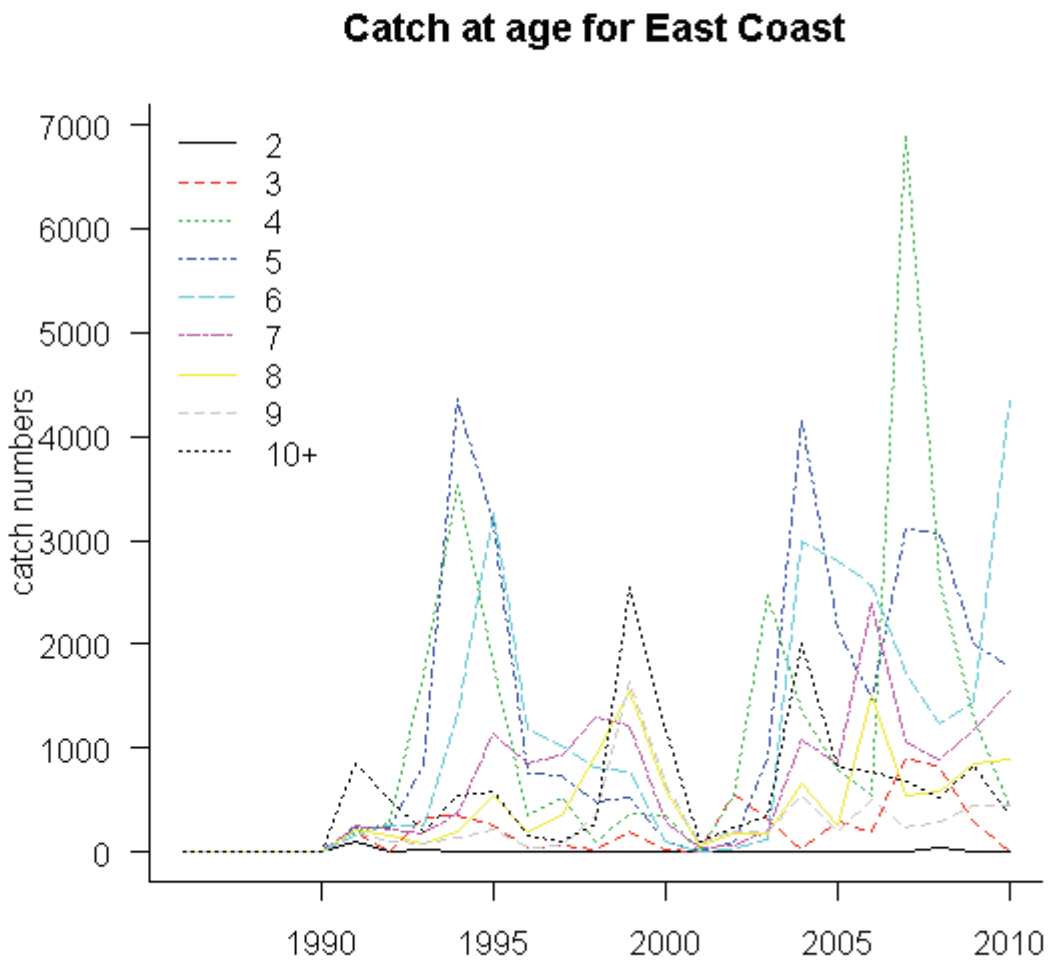


Figure 3.8.1: East Coast. Total catch-at-age numbers (in thousands).

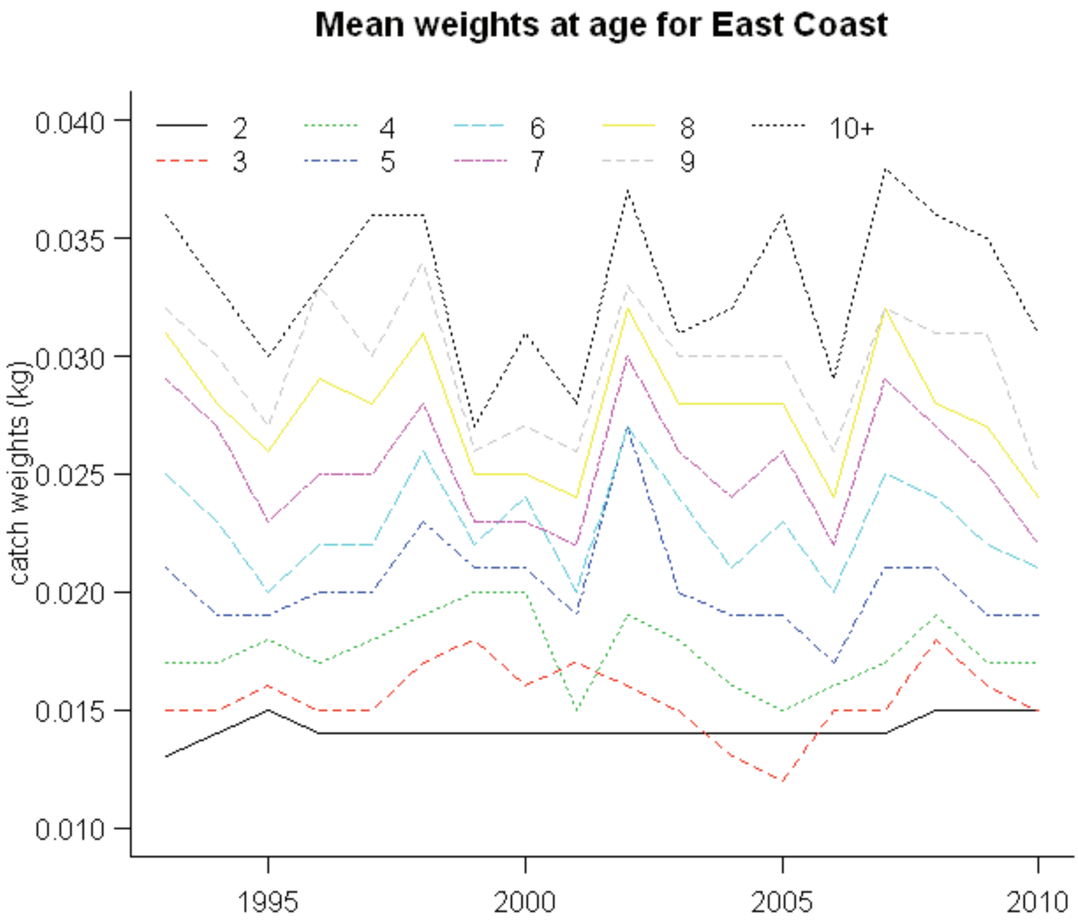


Figure 3.8.2: East Coast. Mean weights-at-age (kg) in total catch (also used for stock weights).

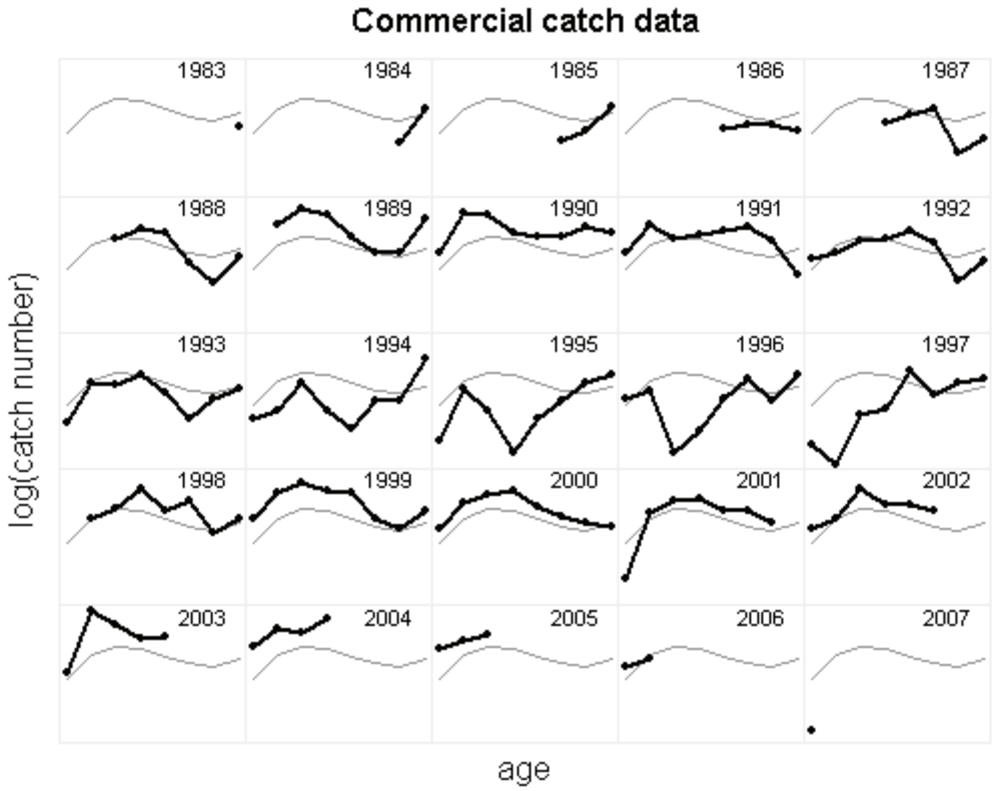
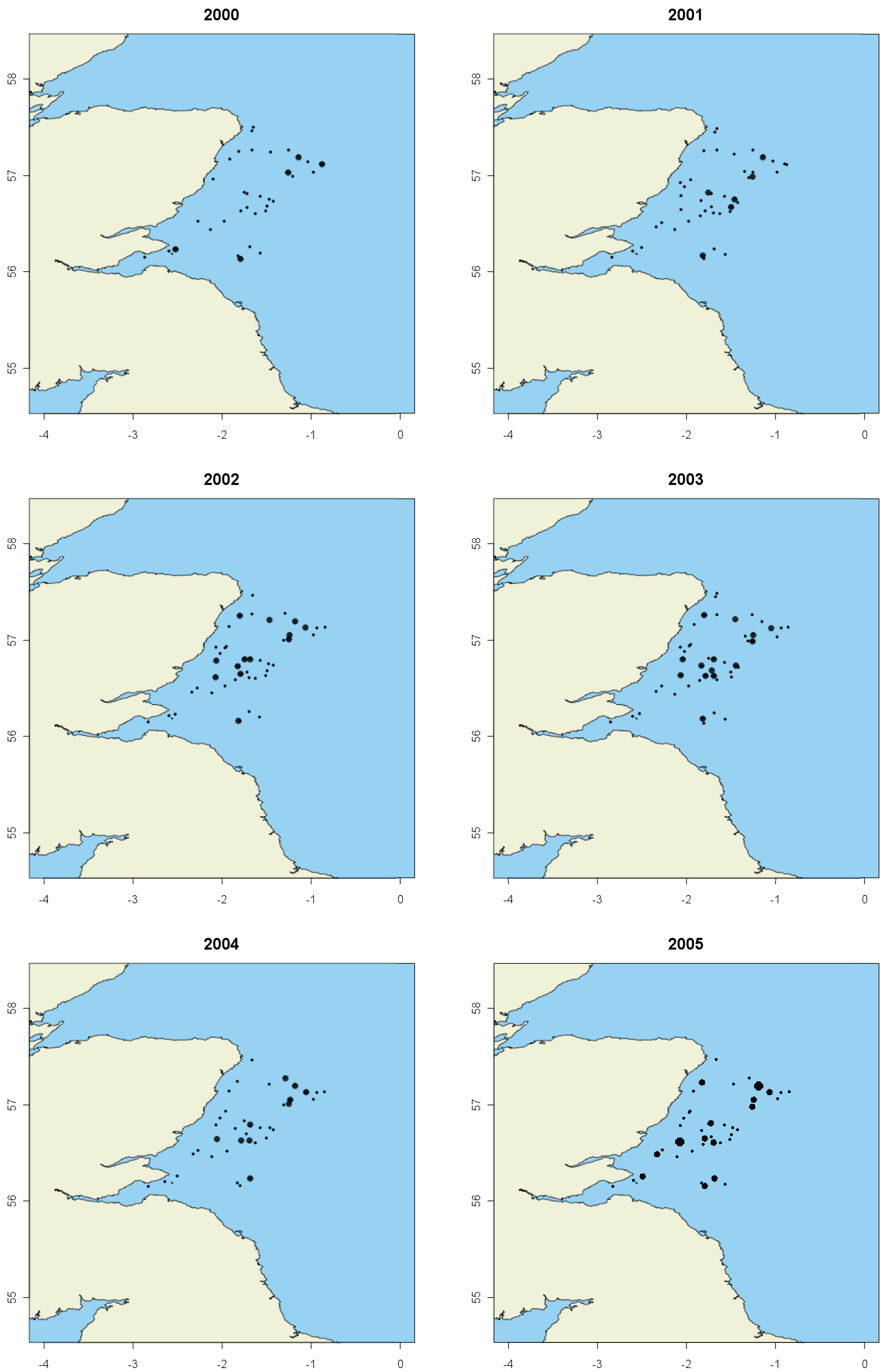


Figure 3.8.3: East Coast. Catch curves from commercial data (ages 3 – 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.


2000
2001
2002
2003
2004
2005
58
57
56
55
-4
-3
-2
-1
0

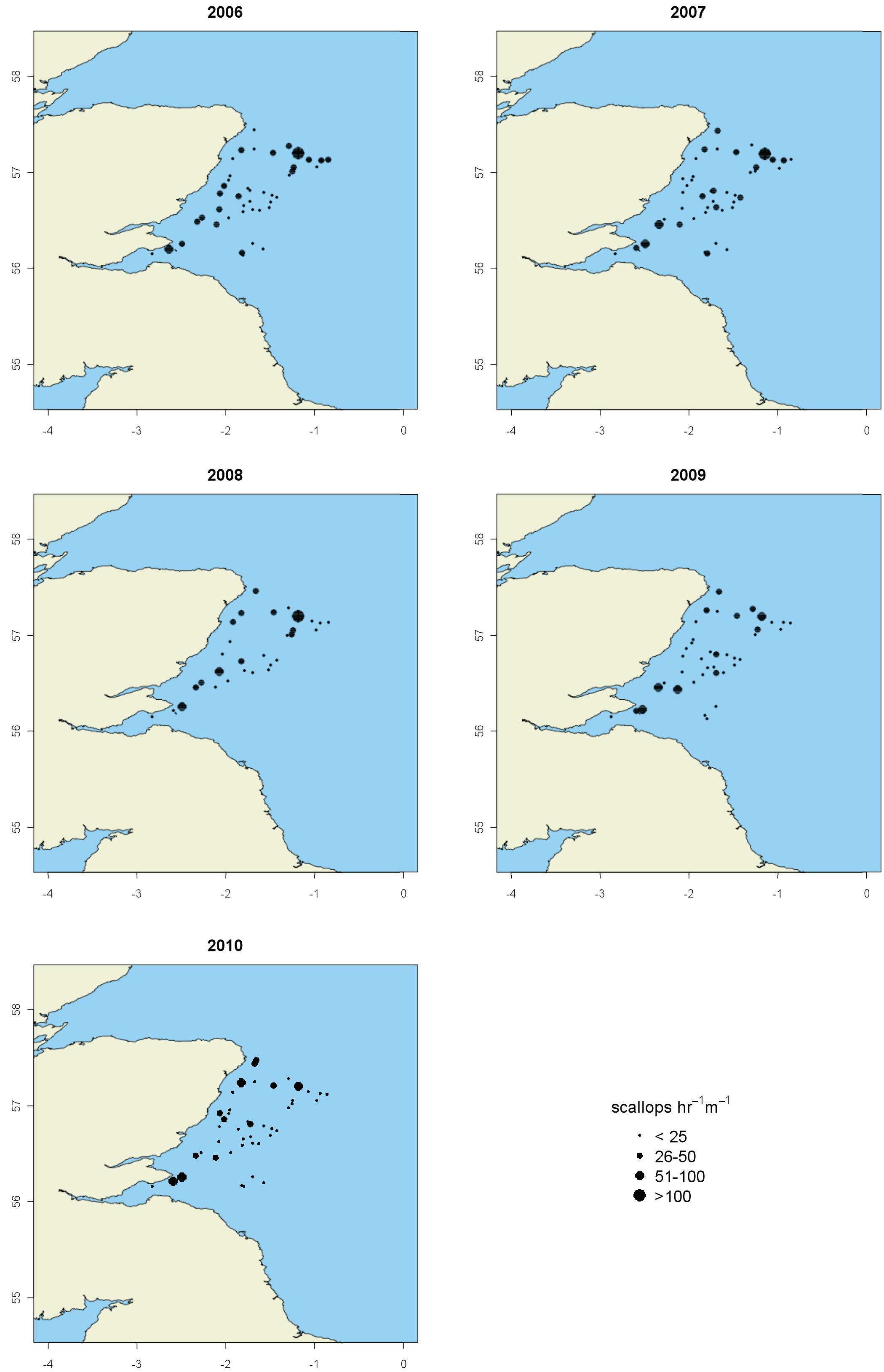


Figure 3.8.4: East Coast. Distribution of dredge survey catch rates (2000-2010).

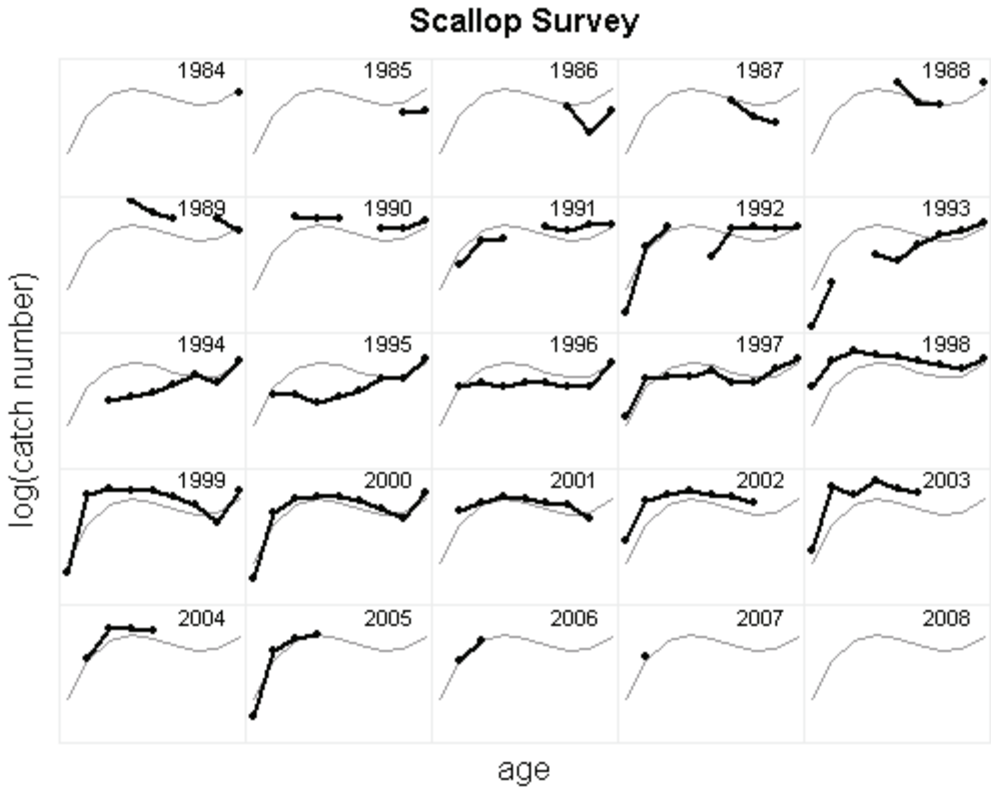


Figure 3.8.5: East Coast. Catch curves from survey data (ages 2 – 10+) by cohort (year class). The bold line represents log catch number and for reference the average log catch curve is shown in grey.

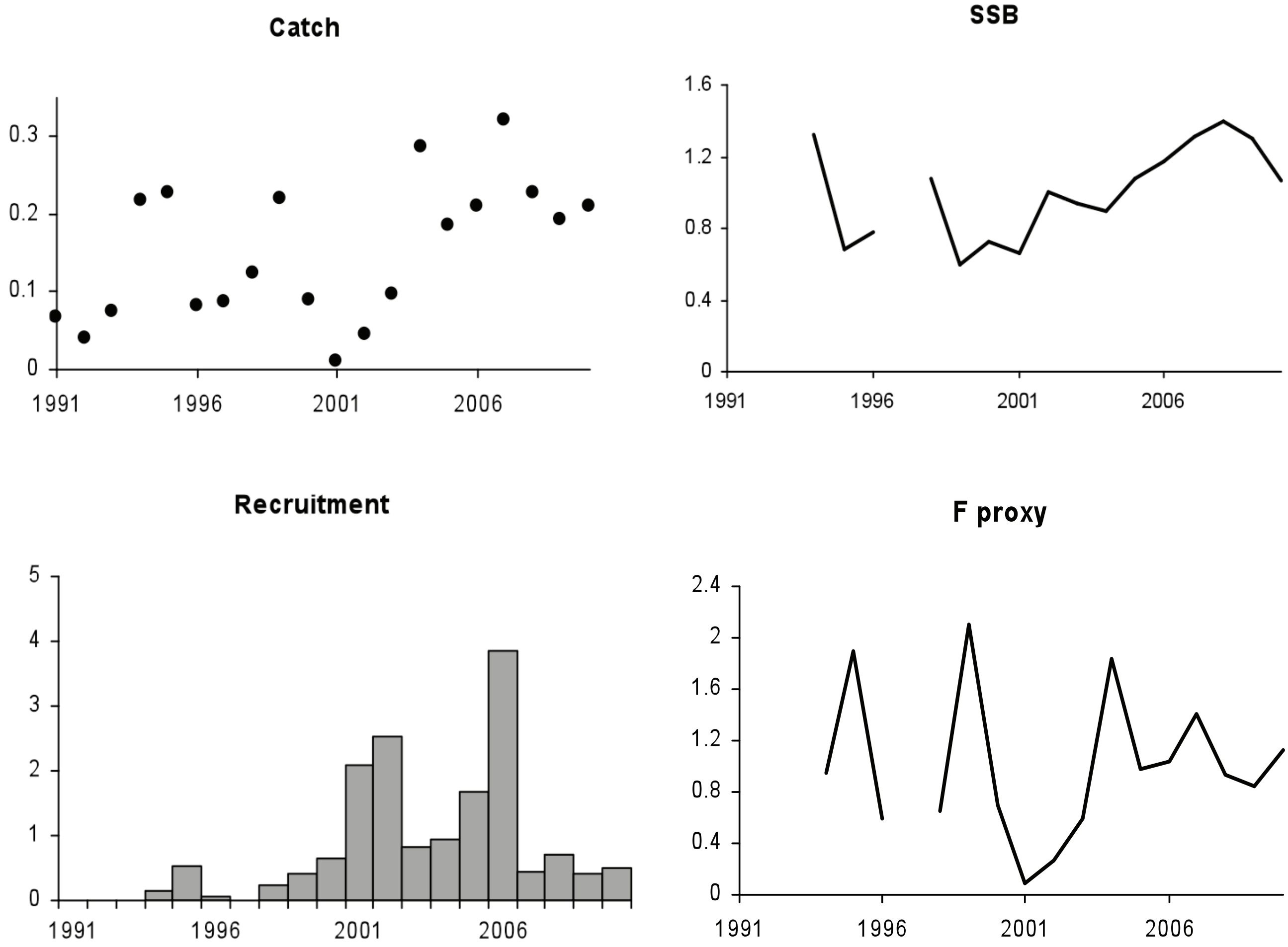


Figure 3.8.6: East Coast. Stock summary (trends only): reported landings (muscle weight of catch in thousand tonnes), SSB and recruitment indices derived from the survey index (mean standardised) and mean standardised F proxy (ratio of catch to SSB). No survey in 1997.

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The Scottish Government
St Andrew's House
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