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This report presents the results of marine and freshwater scientific work carried out by Marine Scotland Science.

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 data up to 2015 and survey data up to and including 2016. Full analytical assessments are presented for the East Coast, North East, North West, Shetland and West of Kintyre scallop stocks, with catch data presented for the Clyde, Irish Sea and Orkney. The report also provides background information on Scottish fisheries for scallops, a description of the current management and regulatory framework.

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 valuable shellfish fishery in Scotland. In 2015, total landings into Scotland were in excess of 10,000 tonnes with a value at first-sale of almost £23 million.

- The most important areas, in terms of recent landings, are the Irish Sea, West of Kintyre, the North West, North East and East Coast. In 2015, over 75% of 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 and subsequent increased stock abundance.

Stock Trends

- In the East Coast assessment area, relatively high recruitment appears to have maintained spawning stock biomass (SSB) and landings above average between 2005 and 2014. Current estimates of recruitment for 2015 and 2016 are, however, particularly low and SSB has declined since 2014. The decreasing stock size coupled with the relatively high landings results in a generally increasing trend in fishing mortality (F) since 2011.

- In the North East assessment area, SSB has declined sharply in recent years. Recruitment has declined over the last five years and estimates for 2015 and 2016 are particularly low. F has fluctuated without trend over the last ten years.

- At Shetland, following a number of very strong year classes during the mid-2000s, recruitment is estimated to be more moderate in recent years. The SSB increased during the 2000s to a maximum in 2010, but has been declining since 2012. Fishing mortality has increased since 2009, in line with the increase in landings, but is still at around the long term average.

- In the North West assessment area, following a period of lower recruitment in the mid-2000s, estimated recruitment has increased and has been above the long term average since 2010. As a result of this and moderate landings, estimated SSB has increased steadily over this period. Recent estimates of fishing mortality are fairly stable at around the long term average.

- In the West of Kintyre assessment area, recruitment is estimated to have increased substantially since 2000 resulting in the highest estimated SSB of the time series in 2012. Since then the stock has remained relatively stable at a high level. This increase in stock size means that despite an increase in landings since 2011, fishing mortality remains relatively low.

- 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' advice for assessed stocks is provided on the basis of estimates of recent fishing mortality, recruitment and biomass in relation to historical values.

- For the East Coast, North East and Shetland assessment areas, where recruitment and SSB have declined, advice is for no increase in fishing effort and consideration of measures to protect the spawning stock.

- In the North West and West of Kintyre assessment areas, advice is for no increase in fishing effort.

- Several administrations have interests and responsibilities for scallop fisheries in the Irish Sea. There is a need to bring together data from different sources and to develop a more consistent, inclusive approach to the assessment and management of stocks in the area.

- Options for the development of MSY reference points or MSY proxies are discussed in this report. It is hoped to investigate these ahead of the next assessment scheduled for 2018/19.

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 makes use of commercial catch-at-age and survey indices by age and can cope with the omission of poor quality or missing data. 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.

- In some assessment areas, commercial sampling levels have fallen in recent years. 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.

- MSS dredge surveys are an essential component of the assessment in that they provide fishery independent indices of abundance. They provide reasonably good coverage of the fished areas as indicted by scallop dredge VMS data (over the period for which these data are available) except in the West of Kintyre assessment area. This could potentially result in biased abundance indices. Additional (or a redistribution of) survey stations in this area may provide a more representative index.

- The population structure of Scottish scallop stocks is not well understood. The assessment areas were defined in relation to the characteristics of the fisheries in the past and may not take account of any connectivity between scallop populations or be the most appropriate management units given modern day fishing patterns.

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 around the rest of the west coast of Scotland, Shetland and the northeast Scottish coast. It is now a year round activity with some fishing grounds up to 40 miles from the coast.

In 2015, total scallop landings into Scotland were in excess of 10,500 tonnes, which with a first-sale value of over £22.5 million made the fishery the second most important shellfish fishery in Scotland. Over 90 % of the landings came from dredge fisheries and most of the remainder was 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 over 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 specified through EU and Scottish 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). Scottish legislation implemented in mid-2017 increases the MLS to 105 mm for UK vessels in all areas around

Scotland excluding the Irish Sea and Shetland (The Regulation of Scallop Fishing (Scotland) Order 2017).

All vessels fishing commercially for scallops in Scotland are required to have a licence and no new licences 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 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. The Regulation of Scallop Fishing (Scotland) Order 2017 now restricts vessels within 12 nautical miles to a bar length that can carry up to eight dredges, although vessels wishing to continue to tow 10 per side in the 6-12 mile zone may do so if they agree to have a remote electronic monitoring (REM) system installed. In addition, a number of areas around Scotland are subject to seasonal (e.g. Luce Bay) or other temporal closures (e.g. weekend ban in the Clyde) and there are also a number of marine protected areas (MPA) in which dredge fishing is banned (e.g. South Arran MPA, Wester Ross MPA) (Scottish Government, 2016).

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 ten dredges in total 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 and Sea Fishing Licensing Regulations 2015*)*. 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 (International Council for the Exploration of the Sea) 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. Note that the partition of landings into the two components relies on the accurate recording of the 'zone variable' by Marine Scotland (MS) fishery officers in the Fisheries Information Network (FIN) database.

2.2 Fishery Data

The stock assessments use various fishery data which are described 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). Recent landings data (2011-2015) for scallops caught in Scottish assessment areas but landed into ports in the Isle of Man and the rest of the UK (excluding Scotland) were provided by the Marine Scotland Marine Analytic Unit from the iFISH database. Irish vessels occasionally fish in the west of Scotland scallop assessment areas. Historical landings (typically accounting for < 0.5 % of total landings from this area) have been provided by the Irish Marine Institute and included in the assessments.

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 (using the rings on their shells) with 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.

On a quarterly basis, sampled numbers-at-age data for dredge and dive caught scallops are raised to total dredge and dive landings, respectively. These data are summed across quarters and fishing method 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 for the sampled data are determined using a length-total weight relationship with parameters 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; zero discard mortality is assumed in the stock assessments.

[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

A length-total weight (where weight is shell, gonad and muscle weight) relationship is used to calculate mean weights at age in the sampled data which are then used to raise sampled data to total landings. The parameters of the length-weight relationship (Weight (g) = a x Length (mm)^b) are fixed across stocks and over time and are as follows:

	A	B	Source
Total (annual)	0.001142	2.513	Cook *et al.* (1990)

The mean weight at age estimates are also used in the stock assessments to convert the outputs (which are in terms of numbers) into total 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 use of total live weight in the stock assessment results differs to the approach taken in earlier stock assessments (Dobby, *et al*., 2012) in which output was provided in terms of muscle weight. The change has been made so that the stock assessment outputs are presented in the same metric as the reported landings (i.e. live weight).

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 (typically between January and June) 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

As in the previous round of Scottish scallop assessments (Dobby et al., 2012) analytic stock assessments were conducted using the Time Series Analysis (TSA) approach as it is was deemed to have a number of advantages over typical Virtual Population Analysis (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.

The TSA assessment method 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 numbers 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 unscented Kalman filter, which is a development of the standard Kalman filter for use in highly non-linear models, 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 (UK vessels into Scotland) scallop landings have fluctuated between eight and 11 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 2015 and over a 45 year 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 throughout this period of time whilst in other areas such as the East Coast, North East and Orkney, fisheries developed relatively recently. The Irish Sea, Orkney and Shetland 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 much lower landings in recent years.

The spatial distribution of landings (vessels of all nationalities) into Scotland in 2015 is shown in Figures 3.1.2 (dredge caught) and 3.1.3 (dive caught). The grounds of greatest importance to the Scottish dredge fishery in 2015 were 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) and are hence not shown in this figure. Total landings into all countries are given in Table 3.1.3. In contrast to the dredge fisheries, the main dive fisheries in 2015, (Figure 3.1.3 and Table 3.1.2) were located in the coastal waters of the west of Scotland and at Orkney, where diving accounted for over 30% of the landings in 2015.

3.2 Clyde

3.2.1 Description of the Fishery

Landings from this area have fluctuated markedly, declining to under 20 tonnes in 1990 and increasing since then to average over 600 tonnes per year since 2011 (Figure 3.1.1). The majority of landings come from the eastern half of statistical rectangle 40E4. Note that the partitioning of landings from statistical rectangle 40E4 into east (Clyde) and west (West of Kintyre) components relies on the accurate recording of the 'zone variable' by MS fishery officers in the Fisheries Information Network (FIN) database. The proportion being recorded as coming from the Clyde has increased significantly in recent years. It is not clear whether this reflects a change in the distribution of the fishery or whether there have been changes in recording practices. Landings from the Clyde may therefore be overestimated in recent years.

The local fleet comprises of a few large vessels which fish out of Campbeltown plus a number of small vessels (< 12 m) fishing out of Girvan, Stranraer and Tarbert. Up to six vessels from the Isle of Man fleet fish in the Clyde at various times of the year.

3.2.2 Sampling Levels and Age Compositions

Since 2010, landings sampling levels in the Clyde assessment area have been much improved. In 2015, almost 3,000 scallops were measured from 14 fishing trips. (Table 3.2.1).

Catch-at-age Data

Raised catch-at-age data for the Clyde area are available in FMD from 1982 onwards. Given the low historical sampling levels, much of these data are not deemed of sufficient quality for further analysis and only data from the most recent five years are presented here (Table 3.2.2).

3.2.3 Assessment

Due to the limited port sampling before 2011, the time series of age composition data is of insufficient length for stock assessment purposes. No survey data are available for the Clyde assessment area.

3.3 East Coast

3.3.1 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 current East Coast scallop fleet consists of 14 vessels that fish year round, operating out of ports along the Aberdeenshire coast from Fraserburgh to Montrose. In addition, up to 15 nomadic boats join the fleet at the end of April coming from the Isle of Man, the English Channel and the Scarborough coast with vessels ranging in size from 14 to 32 m. The fishery has a seasonal trend which typically peaks in the second quarter. It is not uncommon for areas off the Firth of Forth and Bell Rock to be intensively fished.

3.3.2 Sampling Levels and Age Compositions

Sampling of the landings has been carried out since the beginning of the fishery (Table 3.2.1). 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 been variable since then with only six trips sampled in 2014. In 2015, sampling levels were better with 12 trips and 2,636 individuals measured.

Catch-at-age Data

Catch-at-age data for the East Coast are shown in Figure 3.3.1 and Table 3.3.1 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+). The catch-at-age data show consistently lower numbers of individuals at younger ages (two and three year olds) indicating only partial recruitment to the fishery up to age five.

3.3.3 Biological Data

The mean weights at age are shown in Figure 3.3.2 and Table 3.3.2. There are no apparent systematic temporal trends although inter-annual fluctuations in mean weight at age are similar across age classes.

3.3.4 Exploratory Analysis

Catch Data

Mean standardised catch-at-age data by proportion are shown in Figure 3.3.3 with dark bubbles illustrating above average values. The data provide some indications of relative year class strength, with the 1989 and 1999 year classes (recruiting at age three in 1992 and 2002) appearing well above average and those of the mid 1990s being particularly low. These strong year classes are well tracked at subsequent ages. In recent years, the data appear to be more noisy and it is difficult to identify clear year class signals.

Survey Data

Details of the surveys which have been carried out in the East Coast assessment area are given in Table 3.3.3. A partial North Sea scallop survey was conducted in 1993, with full coverage of the East Coast assessment area beginning in 1994. However, the survey was not conducted consistently by the same vessel (RV Clupea) until 1997 onwards with a change to RV Alba na Mara in 2008. No comparative tows were conducted to compare catch rates between vessels. Previous scallop stock assessments have suggested that despite standardisation of catch rates (to account for differences in the number of dredges towed and dredge width), survey vessel may have a significant impact on catchability. Therefore, in this assessment, the survey data are treated as two separate time series. The Clupea dredge survey runs from 1998 to 2007 and the Alba survey from 2008 onwards (Table 3.3.4). Since 2001, the survey has been relatively consistent in terms of timing (June/July). However, prior to this the survey was conducted towards the end of the year (September-December) and in one instance in the following calendar year (1998 survey conducted in January/February 1999). No adjustments are made to the data to account for these differences in timing, but using a model which allows for transient changes in survey catchability enables the assessment to account for the potential impact of such changes.

The catch rates of scallops (age three and 4+ separately) at stations across the East Coast assessment area between 2013 and 2016 are shown in Figure 3.3.4. Most noticeable is the almost complete absence of age three individuals (age at recruitment in the stock assessment) in 2016. In 2015, catches of recruits were largely confined to a few hauls in a small area off the north Aberdeenshire coast. In comparison, in 2013 and 2014, age three individuals were more widely caught, particularly at the offshore stations on the east coast of Scotland. Scallops of age four and above were caught at all survey stations in the East Coast area in 2016, but catch rates were generally lower than in previous years.

Mean standardised survey catch rates at age are shown in Figure 3.3.5 for the two surveys separately (Clupea and Alba). Following a number of weak year classes during the mid-1990s,(apparent as significantly below average catches of older individuals in the early 2000s), the Clupea survey suggests good recruitment in 2001 and 2002 and tracks these cohorts with above average catch rates across a range of age classes. The early part of the Alba survey also picks out the 2003 and 2004 year classes (recruitment in 2006 and 2007) as strong. In more recent years, year class strength signals in the survey are less clear.

A comparison of commercial catch-at-age data and survey indices is shown in Figure 3.3.6 (mean standardised at age over the common time period for each survey). The indices from the Clupea survey are very consistent with the catch-at-age data, particularly from ages five to eight. The two data sources provide very similar estimates of relative year class strength over a number of years. The Alba survey is also relatively consistent with the commercial catch-at-age data in terms of trends, although actual estimates of relative year class strength differ to those from the catch data.

Table 3.3.4 shows the average catch rates by age class and year. Catch rates of ages two and three tend to be lower than other age classes (particularly for the Alba), indicating a lower survey catchability.

3.3.5 Final Assessment

TSA

The exploratory catch and survey data analysis indicates highly variable catch rates of age two individuals. 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.

Recruitment occurs at age three and is implemented as a random walk (with parameters to be estimated) as there is no apparent relationship between SSB and recruitment.

Both the Clupea and Alba survey time series are included in the assessment. The coefficient of variation (cv) multiplier on each survey is adjusted to reflect the varying number of hauls. This allows for survey indices from years in which a greater number of survey hauls were conducted to be given more weighting in the assessment. Based on inspection of preliminary assessment residual plots, greater variability was allowed in particular age classes in the survey data and in both fishing mortality and recruitment in a number of years (by using a cv multiplier above one). The final TSA input settings are given in Table 3.3.5.

Outputs from the TSA assessment are shown in Figure 3.3.7 and estimated parameter values are given in Table 3.3.6. Standardised residuals from the assessment model are shown in Figures 3.3.8 (landings) and 3.3.9 and 3.3.10 (surveys). The landings residuals are well distributed and do not suggest the model is predicting landings with systematic differences to the observations. There is some evidence of a trend in the residuals in the Clupea survey at ages five and six. However, the values are low, and alternative assessment model runs which allowed for a persistent trend in survey catchability estimated the trend to be not significantly different to zero. The best model was therefore deemed to be one which only accounted for transient changes in survey catchability.

There is no clear relationship between stock size (SSB) and recruitment to the fishery (at age three) for this stock (Figure 3.3.11). The recruitment time series with underlying estimated random walk is shown in Figure 3.3.12.

Retrospective Analysis

The retrospective plots shown in Figure 3.3.13 indicate that the assessment tends to underestimate the recruitment, and consequently the SSB, in the final year (i.e. that estimates are revised upwards with each additional year's data). This appears to be due to a revision in the recruitment random walk model with the addition of each subsequent year of data. Mohn's ρ (average under/over estimation) is often used as a measure of assessment performance. For SSB, this is calculated as -0.25 (averaged over the last five assessments) i.e. 25 % underestimation of SSB. There is also some associated over-estimation of fishing mortality, although this is not apparent in all years, and with the exception of the 2013 model run, final year estimates are all within the confidence intervals of the estimates from the final model run.

Stock Summary

Estimates (and standard errors) of age structured population abundance and fishing mortality are presented in Tables 3.3.7 – 3.3.10. 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 3.3.6.

The state of the stock is summarised in Figure 3.3.7 and Table 3.3.11.

The final estimates for the stock are:

F in 2015 (average over ages 4 – 6) = 0.225
SSB in 2016 (total over ages 3 – 10+) = 9728 t

There are currently no reference points for this stock.

Following a number of very strong year classes during the early and mid-2000s, more moderate recruitment is estimated for the late 2000s. Recruitment in 2015 is estimated to be below average and in 2016 to be one of the lowest of the time series, although this latter estimate is based only on a single survey data point and as a result is very uncertain. The SSB increased during the 2000s, but has been declining since 2013. Mean F(4-6) showed a significant decline between 2004 and 2011, but since then is estimated to have doubled.

3.3.6 Comparison with Previous Assessments

This is the first time that an analytical stock assessment has been presented for the East Coast assessment area. The last Scottish scallop assessment report was published in 2012 (Dobby, *et al*., 2012) and presented an empirical assessment based on Scottish dredge survey data for this stock. A comparison between the latest assessment and that given in the 2012 report is presented in Figure 3.3.14. Despite the differences in approach, the historical trends show good agreement, with the main difference being that the results from the latest assessment are much smoother than the indices from 2012 (as would be expected with the application of a population model).

3.3.7 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 Fish 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 since then.

Age Composition

Scallop market sampling levels (number of trips and number of scallops sampled) for the East Coast area have been highly variable. Recent sampling levels are considered adequate and, therefore, the lack of sampling (and resulting lack of catch-at-age data) in 2001 is unlikely to have a significant impact on the assessment of stock status.

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 as inferred from VMS effort data associated with scallop landings (Figure 3.3.15). However, survey station density is relatively low compared to, for example, parts of the Moray Firth coast in the North East assessment area. This is particularly apparent in the offshore areas between Fife and Montrose. Furthermore, in 2015, there also appears to be significant scallop fishery effort along the coast of north Berwickshire, an area which is not covered by the survey, although this is less apparent in earlier 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 both types of dredges. This lower survey catchability results in uncertain estimates of recruitment in the final year.

Retrospective Bias

The assessment shows some tendency towards consistently biased estimates of SSB and F. However, the direction of bias (underestimating SSB, overestimating F) leads to a conservative stock assessment and any resulting advice is therefore more likely to be precautionary.

3.4 Irish Sea

3.4.1 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 and is one of the most important scallop fishing areas around the UK. The fishery began in the 1970s and landings into Scotland steadily increased to a peak of 1,461 t in 2010. Landings into Scotland have decreased since then, but those from the Irish Sea assessment area, have increased with the 2016 landings (5,480 t) being the highest in the time series. The majority are landed into ports outside Scotland with a large proportion taken by non-Scottish vessels. At various times of the year approximately 18 large (14-24 m in length) nomadic Scottish vessels fish the Irish Sea particularly in Luce Bay (seasonally), the scallop grounds off Burrow Head and around the Isle of Man. These vessels normally land at Kirkudbright, Stranraer or the Isle of Whithorn, but depending on fishing locations, they may also land into Peel or Douglas in the Isle of Man.

3.4.2 Sampling Levels and Age Compositions

MSS samples vessel landings at Kirkcudbright (Table 3.2.1) but not on a regular basis. Vessels fishing in the Irish Sea land most of their catch at ports outside Scotland which makes obtaining representative fishery data 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 data are based on a small number of samples taken only at Scottish ports, they are not deemed of sufficient quality for further analysis and are not presented here.

3.4.3 Assessment

The 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. The programme includes dredge surveys of the scallop fishing grounds around the Isle of Man (Murray *et al.,* 2009). However, the results of recent surveys for king scallops are not available at the time of writing.

3.5 North East

3.5.1 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 3,501 t in 1996 but falling to 810 t in 2011 (Figure 3.1.1). Landings in the last three years have been around 2,000 t (above the long term average). The historical fluctuations which are observed in the fishery in this area can partly be explained by effort displacement from areas closed to scallop fishing due to ASP/PSP toxins. Up to 29 large nomadic vessels (over 12 m in length) fish the scallop grounds in the inner and outer Moray Firth, landing into Wick, Buckie and Fraserburgh. At certain times of the year, some of these vessels also fish grounds further north, to the east of the northern Orkney Isles. The main fishery is usually between April and September.

3.5.2 Sampling Levels and Age Compositions

Sampling levels for the North East area are shown in Table 3.2.1. Previously, landings from this area were consistently well sampled, however, in the last 10 years sampling levels have become more variable, possibly a reflection of the variable nature of the fishery.

Catch-at-age Data

Catch-at-age data for the North East are available from 1984 to 2015. The data are shown in Table 3.5.1 and Figure 3.5.1. 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 (with the exception of 2013 where there are a high proportion of 8-10+ in the landings). The catch-at-age data show consistently lower numbers of individuals at younger ages indicating only partial recruitment to the fishery up to age five.

3.5.3 Biological Data

The mean weights at age are shown in Figure 3.5.2 and Table 3.5.2. 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 to more ‘normal’ values. This coincides with the period when sampling levels became more variable and when ages nine and ten plus, in particular, were less apparent in the sampled landings and so may be associated with sampling variability rather than an actual increase in mean size at the older ages. Inter-annual fluctuations in mean weight at age are similar across age classes.

3.5.4 Exploratory Analyses

Catch Data

Mean standardised commercial catch-at-age data by proportion are shown in Figure 3.5.3. Following a period of apparently poor recruitment in the late 1980s, the commercial catch-at-age data suggest above average catches for the 1988 to 1991 cohorts across a range of ages. Data from the more recent period also suggests some years with stronger recruitment, but these signals are less clear and not apparent beyond age seven.

Survey Data

Details of the surveys which have been carried out in the North East assessment area are given in Table 3.3.3. A partial North Sea scallop survey was conducted in 1993, with full coverage of the North East assessment area beginning in 1994. However, the survey was not conducted consistently by the same vessel (RV Clupea) until 1997 onwards with a change to RV Alba na Mara in 2008. No comparative tows have been conducted to compare catch rates between vessels and previous scallop stock assessments have suggested that despite standardisation of catch rates (to account for differences in the number of dredges worked and dredge width), survey vessel may have a significant impact on catchability. Therefore, in this assessment, the survey data are treated as two separate series. The Clupea dredge survey runs from 1997 to 2007 and the Alba survey from 2008 onwards (Table 3.5.3). Since 2001, the survey has been relatively consistent in terms of timing (June/July). However, prior to this the survey was conducted towards the end of the year (September-December), and in one instance in the following calendar year (1998 survey was conducted in January/February 1999). No adjustments are made to the data to account for these differences in timing, but using a model which allows for transient changes in survey catchability enables the assessment to account for the potential impact of such changes.

The catch rates of scallops (age three and 4+ separately) at stations across the North East area between 2013 and 2016 are shown in Figure 3.3.4. In 2013 and 2014 high catch rates of age three individuals (age at recruitment) were observed at many of the stations across the west and north of the Moray Firth. In 2015 and 2016, there is almost a complete absence of age three individuals in the survey with the exception of a very large catch in 2015 off the northeast Aberdeenshire coast. Scallops of age four and above were caught at all survey stations in the North East area in 2016, but survey catch rates were generally lower than in previous years.

Mean standardised survey catch rates at age are shown in Figure 3.5.4 for the two surveys. The Clupea survey estimates the cohorts from the early 1990s to be of above average size and tracks these consistently at older ages in the late 1990s. This survey also estimates the 1994 to 1996 (recruitment in 1997 to 1999) cohorts to be weak consistently across most age classes. The Alba survey data appear much noisier and poorer at tracking cohort strength. With the exception of the 2009 and 2010 year classes from age four onwards, cohort strength estimates from this survey are inconsistent.

A comparison of commercial catch-at-age data and survey indices is shown in Figure 3.5.5 (mean standardised at age over the common time period for each survey). The indices from the Clupea survey are very consistent with the catch-at-age data particularly from ages four to eight. The two data sources provide almost identical estimates of relative year class strength over a number of years and age classes. The Alba survey indices have the same general trend as the catch at age data, but the estimates of relative year class strength differ.

Table 3.5.3 shows the average survey catch rates by age class and year. Catch rates of ages two and three are typically much lower than other age classes (particularly in the Alba survey) indicating significantly lower survey catchability for these age classes.

3.5.5 Final Assessment

TSA

Exploratory data analyses shows low and highly variable catch rates of age two individuals in both the commercial catch and survey data. In addition, the catch rates of the 10+ age group in the survey are considered quite noisy. These data are, therefore, excluded from the final assessment.

Recruitment occurs at age three and is implemented as a random walk (with parameters to be estimated) as there is no apparent relationship between SSB and recruitment.

Both the Clupea and Alba survey time series are included in the assessment. The cv multiplier on each survey is adjusted to reflect the varying number of hauls. This allows for survey indices from years in which a greater number of survey hauls were conducted to be given more weighting in the assessment. Based on inspection of preliminary assessment diagnostic plots, greater variability was allowed in particular age classes in the survey data and in both fishing mortality and recruitment in a number of years (by using a cv multiplier above one). The final TSA settings are given in Table 3.5.4.

Outputs from the TSA assessment are shown in Figure 3.5.6 and estimated parameter values are given in Table 3.5.5. Standardised residuals from the assessment model are shown in Figures 3.5.7 (landings) and 3.5.8 (Clupea survey) and 3.5.9 (Alba survey). Both catch and survey residuals are well distributed about zero and generally small. There is no evidence to indicate any major issues with fitting to the observed data.

There is no clear relationship between stock size (SSB) and recruitment at age three for this stock, although examination of the data suggests that the period of highest recruitment (1989-91 year classes) is associated with low stock size (Figure 3.5.10). The recruitment time series with underlying estimated random walk is shown in Figure 3.5.11.

Retrospective Analysis

The results of the retrospective analysis are shown in Figure 3.5.12. There is some tendency for the assessment to underestimate recruitment and subsequent SSB in the final year of the assessment. Mohn's ρ (average under/over estimation) is calculated as -0.24 (averaged over the last five assessments), i.e. 24 % underestimation of SSB. There is also some associated overestimation of fishing mortality which appears to be significant in the assessment run with final year 2013. Other final year estimates of fishing mortality fall within the confidence bounds of the estimates from the final (2016) model run.

Stock Summary

Estimates (and standard errors) of age-structured population abundance and fishing mortality are presented in Tables 3.5.6-3.5.9. The state of the stock is summarised in Figure 3.5.6 and Table 3.5.10. The final estimates for the stock are:

F in 2015 (average over ages 4-6) = 0.132
SSB in 2016 (total over ages 3-10+) = 9,275 t

There are currently no reference points for this stock.

Fishing mortality on this stock is estimated with considerable uncertainty throughout the time period, but the point estimates show a rapid increase during the late 1980s and early 1990s. In the last ten years, F has fluctuated without significant trend. SSB has declined sharply in recent years after a period of relatively stable/increasing SSB. Recruitment has declined over the last five years and current estimates for 2015 and 2016 are particularly low (although the latter is based only on a single survey data point and is therefore quite uncertain).

3.5.6 Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2012 (Dobby *et al.*, 2012). A comparison between the latest assessment and that given in the 2012 report is presented in Figure 3.5.13. The two assessments show reasonable consistency. However, the latest assessment suggests a greater decline in F than the 2012 assessment over the period 2005 to 2010 and a somewhat greater increase in SSB since the start of the time series. Although the assessments use the same approach (TSA), they differ in that in the latest assessment it was considered more appropriate to treat the survey data as two separate time series while in the earlier assessment the data were combined as a single index.

3.5.7 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 Fish 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 since then.

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.

Survey Data

The scallop grounds of the North East assessment area (inferred from VMS data, Figure 3.3.15) are well covered by the dredge survey. However, there appears to be significant spatial variability in the intensity of survey sampling, 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 (possibly a weather related issue).

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 which results in uncertain estimates of recruitment in the final year.

Retrospective Bias

The assessment shows some tendency towards consistently biased estimates of SSB and F. However, the direction of bias (underestimating SSB, overestimating F) leads to a conservative stock assessment and any resulting advice is therefore likely to be more precautionary.

3.6 North West

3.6.1 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 all year round. In 2015, landings were 2,236 t, 50% of the peak of 4,500 t taken from the area in 2002. The fishery is prosecuted by a fleet of around 10 over-10 m vessels. Most of these vessels operate out of ports in the Outer Hebrides, landing into Grimsay, Scalpay and Stornoway. There are also local dredge vessels operating out of Mallaig and Tobermory which fish to the north of Mull. Additionally, up to six nomadic boats (from Oban and the Isle of Man) sometimes join the fishery at various times of the year. There is also a small but significant dive fishery in which approximately ten vessels regularly participate. The dive fishery operates largely in the sheltered inshore waters around Ardnamurchan, Kyle, Ullapool, Uist and Barra and in 2015 accounted for just over 12% of total scallop landings in the North West area.

3.6.2 Sampling Levels and Age Compositions

The North West area has generally been well sampled since the early 1990s. Sampling levels are shown in Table 3.2.1. In 2015, 7,158 individual scallops were measured from 42 sampled vessels.

Catch-at-age Data

Catch-at-age data for the North West from 1982 to 2015 are shown in Figure 3.6.1 and Table 3.6.1. In the early part of the time series, a significant proportion of catches were of individuals in the 10+ age category, whereas more recently, the catches consist largely of four, five and six year old individuals.

3.6.3 Biological Data

The mean weights at age are shown in Figure 3.6.2 and Table 3.6.2. 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. In 2008, mean weights show a sudden increase across a number of ages (coupled with an unusual age structure, Section 3.6.5) which could be due to either unrepresentative landings being sampled in this year or potentially to errors during the sampling process.

3.6.4 Exploratory Analysis

Catch Data

Mean standardised catch-at-age data by proportion are shown in Figure 3.6.3 with dark bubbles illustrating above average values. There is some evidence that data track relative year class strength during the 1990s and early 2000s. However, the more recent data appear very noisy and the age composition in 2008 in particular shows a very strange pattern with unexpectedly low proportion of older ages and a high proportion of age five and six.

Survey Data

Details of west coast scallop surveys which cover the North West assessment area are given in Table 3.6.3. No comparative tows have been conducted to compare catch rates between vessels and previous scallop stock assessments have suggested that despite standardisation of catch rates (to account for differences in the number of dredges worked by each vessel), survey vessel may have a significant impact on catchability. Therefore, in this assessment, the survey data are treated as three separate indices. The Aora dredge survey runs from 1993 to 2002, the Aora II from 2003 to 2007 and the Alba from 2008 to 2016 (Table 3.6.4). Within each of the three survey indices, the seasonal timing of the survey has been relatively consistent over time.

The catch rates of scallops (age three and 4+ separately) at stations across the North West area between 2013 and 2016 are shown in Figure 3.6.4. In all years there appear to be a significant number of tows where no age three (recruitment age) individuals were caught. However, a general increase in the catch rates of recruits in 2015 and 2016 compared to 2014 is also evident. The catch rates of age 4+ are much higher than those of age three individuals with the highest catches typically occurring in the area between northern Skye and the Outer Hebrides and off southeast Skye.

Mean standardised survey catch rates at age are shown in Figure 3.6.5. There is clear tracking of strong year classes (recruitment in 1992, 2000) in the Aora and Aora II survey series. The early part of the Alba survey also identifies strong (and weak) year classes consistently across a wide range of ages and survey years, but in recent years, the signals are less clear.

A comparison of commercial catch-at-age data and survey indices is shown in Figure 3.6.6 (mean standardised at age over the common time period for each survey). The indices from the Aora and Aora II surveys are most consistent with the catch data at the younger ages while the Alba survey shows more consistency for age five and above.

Table 3.6.4 shows the average catch rates by age class and year. Catch rates of ages two and three are consistently lower than other age classes (particularly for the Alba survey) indicating a significantly lower survey catchability.

3.6.5 Final Assessment

TSA

The exploratory catch and survey data analysis indicates highly variable catch rates of age two individuals. 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.

Recruitment occurs at age three and is implemented as a random walk (with parameters to be estimated) as there is no apparent relationship between SSB and recruitment.

All three survey time series are included in the assessment. Based on inspection of preliminary assessment residual plots, the first two years of the Aora survey (1993 and 1994) were excluded due to apparently much higher survey catchability than the remainder of the time series. The cv multiplier on each survey is adjusted to reflect the varying number of hauls. This allows for survey indices from years in which a greater number of survey hauls were conducted to be given more weighting in the assessment. Initial residual plots also indicate greater variability at particular age classes in the survey data and in both fishing mortality and recruitment in a number of years and the cv multiplier was increased above one in such cases. The rather strange age composition apparent in the 2008 catch data (Figure 3.6.3) appeared to be quite influential in the fitting procedure and hence the decision was made to completely exclude the 2008 catch data. The final TSA settings are given in Table 3.6.5.

Outputs from the TSA assessment are shown in Figure 3.6.7 and estimated parameters given in Table 3.6.6. Standardised residuals from the assessment model are shown in Figures 3.6.8 (landings) and 3.6.9 to 3.6.9.11 (surveys). Both catch and survey residuals are well distributed about zero and generally small. There is no evidence to indicate any major issues with fitting to the observed data.

There is no clear relationship between SSB and recruitment to the fishery (at age three) for this stock (Figure 3.6.12). The recruitment time series with underlying estimated random walk is shown in Figure 3.6.13.

Retrospective Analysis

The retrospective plots are shown in Figure 3.6.14. There is little evidence to suggest systematic underestimation (or overestimation) of either SSB or F and with the exception of the model run ending in 2011, all final year estimates of both SSB and F are within the confidence intervals of the estimates from the final model run (2016). Mohn's ρ (average under/over-estimation) is calculated as -0.08 which is not significant given the uncertainty in the model estimates.

Stock Summary

Estimates (and standard errors) of age structured population abundance and fishing mortality are presented in Tables 3.6.7-3.6.10. 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 3.6.6.

The state of the stock is summarised in Figure 3.6.7 and Table 3.6.11. The final estimates for the stock are:

F in 2015 (average over ages 4-6) = 0.141
SSB in 2016 (total over ages 3-10+) = 17,581 t

There are currently no reference points for this stock.

Following a period of lower recruitment in the mid-2000s, estimated recruitment has increased and has been above the long term average since 2010. As a result of the increased recruitment and moderate landings, estimated SSB has increased steadily over this period. The resulting estimates of recent fishing mortality are fairly stable at around the long term average.

3.6.6 Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2012 (Dobby *et al*., 2012). A comparison between the latest assessment and that given in the 2012 report is presented in Figure 3.6.15. The two assessments show good consistency, particularly in the estimates of fishing mortality. Although the assessments use the same approach (TSA), they differ in that in the latest assessment it was considered more appropriate to treat the survey data as three separate time series while in the earlier assessment the assumption was that the data formed a single index. This is likely to account for the slightly different trends in the SSB estimates over the more recent period (since 2000).

3.6.7 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 Fish 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 since then.

Age Composition

Although market sampling levels across this area have generally been good, there was a period between 2005 and 2009 where sampled numbers declined which may explain the increased variability in catch-at-age composition and mean weights observed in the late 2000s.

Survey Data

Survey stations are located in most of the major scallop grounds of the North West assessment area (inferred from VMS effort data associated with scallop landings, Figure 3.6.16). The exception to this is the area north of Skye where there are a number of offshore survey stations, but few close to the Harris and Lewis coast where there appear to be important scallop 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 which results in uncertain estimates of recruitment in the final year.

Retrospective Bias

The assessment shows good consistency and little evidence of retrospective bias. Only minor revisions are made to the estimated SSB and F when additional data are added to the stock assessment.

3.7 Orkney

3.7.1 Description of the Fishery

The Orkney scallop fishery began in the 1970s but has remained relatively small in comparison to fisheries in other assessment areas. The scallop dredge fleet in Orkney consists of three local vessels which work year round, plus an additional visiting vessel at various times of the year. The fleet land into Hoy, Kirkwall and Westray. There is also a significant dive fishery in Orkney in which 13 vessels participate. These vessels operate year round and land into Burray, Kirkwall and Stromness.

3.7.2 Sampling Levels and Age Compositions

Very limited sampling of recent landings was achieved in this fishery: a total of 3,422 scallops were measured during 2011-2015 (Table 3.2.1). 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.

3.7.3 Assessment

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

3.8 Shetland

3.8.1 Description of the Fishery

The Shetland scallop fishery developed in the late 1960s and landings have shown a generally increasing trend since then. In recent years landings have been around 1,000 t, with the exception of 2013 when landings exceeded 1,400 t. Up to eight large scallops vessels (>10 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. A further 20 dredge vessels less than 10 m in length are licensed under the Regulating Order (RO) by the SSMO to fish at Shetland.

3.8.2 Sampling Levels and Age Compositions

The landings from the Shetland area have been consistently well sampled since the late 1980s. (Table 3.2.1). In 2015, almost 7,000 individual scallops were aged and measured from 71 sampled trips.

Catch-at-age Data

Catch-at-age data for Shetland are shown in Table 3.8.1 and Figure 3.8.1 for 1986 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, particularly in the early years of sampling.

3.8.3 Biological Data

The mean weights at age are shown in Figure 3.8.2 and Table 3.8.2. There is a gradually increasing trend in mean weight-at-age over all ages through the 2000s which appears to have levelled off, or in fact reversed, more recently. Inter-annual fluctuations in mean weight-at-age are similar across age classes.

3.8.4 Exploratory Analysis

Catch Data

Mean standardised catch-at-age data by proportion are shown in Figure 3.8.3 with dark bubbles illustrating above average values. There is some evidence that data track relative year class strength during the 1990s and early 2000s although during this latter period relative year class strength is not tracked consistently over all ages.

Survey Data

Details of the surveys which have been carried out at Shetland are given in Table 3.8.3. Typically, the survey has been carried out in the first quarter of the year, 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 two early surveys were also conducted by a different vessel and are therefore excluded from the assessment. From 1998 to 2008, the survey was conducted by the RV *Clupea* and since then by the RV *Alba na Mara*. No comparative tows were conducted to compare catch rates between vessels and previous scallop stock assessments have suggested that despite standardisation of catch rates (to account for differences in the number of dredges worked and dredge width), survey vessel may have a significant impact on catchability. Therefore, in this assessment, the survey data are treated as two separate time series.

The number of valid survey stations varies considerably, with bad weather often disrupting the survey. Typically, the stations which are missed due to bad weather are 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 survey indices derived from surveys with fewer tows are expected to be more uncertain and are given less weight in the stock assessment by adjusting their weighting according to the varying number of hauls. Note that not even a partial survey of the area could be conducted in either 2014 or 2015.

The catch rates of scallops (age three and 4+ separately) at stations across the Shetland area during 2013 and 2016 are shown in Figure 3.8.4. In the limited number of hauls conducted in 2016, there appears to be a lower proportion of tows than in 2013 where zero age three (recruitment age) individuals were caught. Over the common tows, catch rates of age 4+ are comparable between the two years.

Mean standardised survey catch rates at age are shown in Figure 3.8.5. Weak year classes from the mid-1990s (recruiting in 1997 to 1999) are tracked consistently by the Clupea survey, and towards the end of that survey, the 2003 year class is consistently estimated as above average. The Alba survey data appear quite noisy and are even more difficult to interpret given the discontinuities in the time series. In 2011 and 2012 in particular, this survey appears to suffer from year effects with the 2011 data all being above average and 2012 below average.

A comparison of commercial catch-at-age data and survey indices is shown in Figure 3.8.6 (mean standardised at age over the common time period for each survey). The indices from the Clupea survey show good consistency with the commercial catch-at-age data up to age nine. The Alba survey series is so short relative to the commercial fishery data that it is difficult to make a comparison of trends between the two series.

Table 3.8.4 shows the average catch rates by age class and year. Catch rates of ages two and three are consistently lower than other age classes (particularly for the Alba survey) indicating a significantly lower survey catchability.

3.8.5 Final Assessment

TSA

The exploratory catch and survey data analysis indicates highly variable catch rates of age two individuals. 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.

Recruitment occurs at age three and is implemented as a random walk (with parameters to be estimated) as there is no apparent relationship between SSB and recruitment.

Both the Clupea and Alba survey time series are included in the assessment. The coefficient of variation (cv) multiplier on each survey is adjusted to reflect the varying number of hauls. This allows for survey indices from years in which a greater number of survey hauls were conducted to be given more weighting in the assessment. Based on inspection of preliminary assessment residual plots, greater variability was allowed in particular age classes in the survey data and in fishing mortality, and recruitment in a number of years (by using a cv multiplier above one). The final TSA input settings are given in Table 3.8.5.

Outputs from the TSA assessment are shown in Figure 3.8.7 and estimated parameter values are given in Table 3.8.6. Standardised residuals from the assessment model are shown in Figures 3.8.8 (landings) and 3.8.9 and 3.8.10 (surveys). The residuals show some tendency for model over-prediction of landings at age six and also either a positive trend or reduced variability in landings residuals at ages seven and eight. These patterns appear to be associated with changes in the fishing mortality at age which the TSA is unable to model appropriately even with an increase in the variability of fishing mortality at age for ages three and four. The survey residuals are well distributed and relatively small.

There is no clear relationship between stock size (SSB) and recruitment to the fishery (at age three) for this stock (Figure 3.8.11). The recruitment time series with underlying estimated random walk is shown in Figure 3.8.12.

Retrospective Analysis

The retrospective plots shown in Figure 3.8.13 suggest that the assessment is prone to underestimation of the recruitment, and consequently the SSB, in the final year (i.e. that estimates are revised upwards with each additional year’s data). However, this bias does not occur consistently across all years. It is much less apparent in the most recent years (three retrospective years) when only minor revisions occur and in these cases, final year estimates are all well within the confidence intervals of the estimates from the final (2016) model run. Mohn's ρ (average under/over estimation) is often used as a measure of assessment performance. For SSB, this is calculated as -0.15 (averaged over the last five assessments) i.e. 15 % underestimation of SSB. Associated over-estimation of fishing mortality is also only apparent in retrospective runs ending in 2012 and earlier.

State of the Stock

Estimates (and standard errors) of age structured population abundance and fishing mortality are presented in Tables 3.8.7 – 3.8.10. 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 3.8.6.

The state of the stock is summarised in Figure 3.8.7 and Table 3.8.11. The final estimates for the stock are:

F in 2015(average over ages 4-6) = 0.153
SSB (total over ages 3-10+) = 5074 t

There are currently no reference points for this stock.

Following a number of very strong year classes during mid-2000s, recruitment is estimated to be more moderate in recent years (although estimated with considerable uncertainty). The SSB increased during the 2000s to a peak of over 8000 t in 2010, but has been declining since 2012. Mean F(4-6) has increased since 2009, in line with the increase in landings, but is still at around the long term average despite the high landings (due to the currently greater stock size).

3.8.6 Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2012 (Dobby *et al.*, 2012). A comparison between the latest assessment and that given in the 2012 report is presented in Figure 3.8.14. The two assessments show good consistency, in the estimates of fishing mortality and recruitment until the mid-2000s, but since then show differing trends. The main factor contributing to this difference is the alternative assumptions about the survey data with the earlier assessment treating the survey data as a single survey index while in the most recent assessment it was considered more appropriate to treat the data as two separate time series. In addition, a number of revisions have been made to historical landings data (higher landings in some years in the most recent assessment) due to delays with data entry into the FIN database.

NAFC Marine Centre also conduct stock assessments of the scallops around Shetland and provide advice to the SSMO. Their advice on stock status is based on a landings per unit effort (LPUE) series which shows a slight increasing trend in recent years (MSC, 2016). In contrast, results from their quarterly VPA indicate a decline in abundance due to somewhat weaker recent recruitment which is more in line with the assessment presented in this report. NAFC assessments account for only landings by SSMO vessels while the MSS assessment uses total officially reported landings from the Shetland area (including non-SSMO vessels) which may explain some of the differences in the assessment results.

3.8.7 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 Fish 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 since then.

Age Composition

Market samples from the Shetland area are collected and provided by staff from NAFC Marine Centre under a Memorandum of Understanding between NAFC Marine Centre and MSS. Sampling levels for this area are considered to be very good.

Survey Data

A full Shetland scallop survey typically consists of over 60 stations although in recent years this has been substantially curtailed due to poor weather. Figure 3.8.15 shows the standard survey stations in relation to the fishing grounds as inferred from VMS effort data associated with scallop landings. Although there is a high density of stations in some areas, a number of important fishing areas are not surveyed. There are no survey stations located around the Outer Skerries or to the southeast of Whalsay, areas which have been fished regularly in recent years. (Note that in this assessment area, a significant proportion of the landings are taken by < 12 m vessels and therefore the VMS effort plot may not provide a complete picture of the scallop 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 which results in uncertain estimates of recruitment in the final year.

Retrospective Bias

The assessment shows some tendency towards biased estimates of SSB and F (although not consistently over all retrospective runs). However, the direction of bias (underestimating SSB, overestimating F) leads to a conservative stock assessment and any resulting advice is therefore more likely to be precautionary.

3.9 West of Kintyre

3.9.1 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 all year round. Landings have fluctuated between around 500 and 2,500 tonnes over the stock assessment period and in 2016 were 1,412 tonnes (at about long term average). The fishery is prosecuted regularly by a fleet of around 15 vessels which range from 9.9 m to approximately 20 m in length and typically land their catch into Campbeltown, Islay, Tayinloan and West Loch Tarbert. Up to six vessels from the Isle of Man may also fish this area at various times of the year. In addition, three local (< 10 m) vessels and a number of seasonal visiting vessels operate a dive fishery in the inshore waters of the West of Kintyre.

3.9.2 Sampling Levels and Age Compositions

The West of Kintyre area has generally been well sampled since the mid-1980s. Sampling levels are shown in Table 3.2.1. In 2015, 5,257 individual scallops were measured and aged from 31 sampled trips.

Catch-at-age Data

Catch-at-age data for the West of Kintyre, from 1982 to 2015 are shown in Table 3.9.1 and Figure 3.9.1. In the early part of the time series, scallops of age 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 to seven in the catch has increased considerably since this time. The number of age two individuals in the catch has also reduced over time.

3.9.3 Biological Data

The mean weights at age are shown in Figure 3.9.2 and Table 3.9.2. The mean weights of individuals aged four to seven show a gradual decline since the mid-1990s. Mean weights for those age categories which are less important in the catch (particularly ages nine and 10+) show greater variability and temporal trends which are similar across age classes.

3.9.4 Exploratory Analyses

Catch Data

Mean standardised catch-at-age data by proportion are shown in Figure 3.9.3 with dark bubbles illustrating above average values. Despite the good sampling levels, the commercial catch-at-age data appear very noisy for the West of Kintyre. The data identifies a period of weak year classes during the late 1980s which are picked up in the data as below average catches at older ages in the early 1990s. Following that there is some evidence of stronger recruitment in the early 1990s and again in the late 2000s. However, relative year class strength is generally not consistently tracked through cohorts in these data.

Survey Data

Details of west coast scallop surveys which cover the West of Kintyre assessment area are given in Table 3.6.3. No comparative tows have been conducted to compare catch rates between vessels and previous scallop stock assessments have suggested that despite standardisation of catch rates (to account for differences in the number of dredges worked by each vessel), survey vessel may have a significant impact on catchability. Therefore, in this assessment, the survey data are treated as three separate indices. The Aora dredge survey runs from 1993 to 2002, the Aora II from 2003 to 2007 and the Alba from 2008 to 2016 (Table 3.9.3). Within each of the three survey indices the seasonal timing of the survey has been relatively consistent over time.

The catch rates of scallops (age three and 4+ separately) at stations across the West of Kintyre area between 2013 and 2016 are shown in Figure 3.6.4. High catch rates of age three scallops are apparent in the 2013 survey in particular, suggesting good recruitment in that year. In general, the catch rates of age 4+ are much higher than those of age three individuals with consistently good catch rates across the West of Kintyre over the period shown.

Mean standardised survey catch rates at age are shown in Figure 3.9.4. On the whole the survey data appear quite noisy. The Aora survey identifies, year classes recruiting in the mid-1990s as above average although the 1996 data show a strong negative year effect with almost all ages caught at below average rates. The weak 1998 year class (recruitment at age three in 2001) is consistently estimated below average across the Aora and Aora II survey series up to age eight. The Alba survey data provide some evidence of strong recruitment in the late 2000s, but relative year class strength is not estimated consistently at older ages.

A comparison of commercial catch-at-age data and survey indices is shown in Figure 3.9.5 (mean standardised at age over the common time period for each survey). The general trends in the Aora survey and commercial data are in general agreement over ages four to nine. The Alba survey also shows some consistency with the catch-at-age data, particularly in identifying strong recruitment (age three) in 2010.

Table 3.9.3 shows the average catch rates by age class and year. Catch rates of ages two and three are consistently lower than other age classes (particularly for the Alba survey) indicating a significantly lower survey catchability.

3.9.5 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.

Recruitment occurs at age three and is implemented as a random walk (with parameters to be estimated) as there is no apparent relationship between SSB and recruitment.

All three survey time series are included in the assessment. The cv multiplier on each survey is adjusted to reflect the varying number of hauls. This allows for survey indices from years in which a greater number of survey hauls were conducted to be given more weighting in the assessment. Based on inspection of preliminary assessment residual plots, greater variability was allowed in particular age classes in the survey data and in fishing mortality in a number of years (by using a cv multiplier above one). The final TSA settings are given in Table 3.9.4.

Outputs from the TSA assessment are shown in Figure 3.9.6 and estimated parameters given in Table 3.9.5. Standardised residuals from the assessment model are shown in Figures 3.9.7 (landings) and 3.9.8-10 (surveys). Both catch and survey residuals are well distributed about zero and generally small. There is no evidence to indicate any major issues with fitting to the observed data.

There is no clear relationship between SSB and recruitment to the fishery (at age three) for this stock (Figure 3.9.11). The recruitment time series with underlying estimated random walk is shown in Figure 3.9.12.

Retrospective Analysis

The retrospective plots are shown in Figure 3.9.13. There is some evidence to suggest that the assessment tends to underestimate SSB (and slightly overestimate F) in the final year, as estimates are revised upwards with each additional year's data. Mohn's ρ (average under/over-estimation) is calculated as -0.12 i.e. 12 % underestimate of SSB.

Stock Summary

Estimates (and standard errors) of age structured population abundance and fishing mortality are presented in Tables 3.9.6-3.9.9. 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 3.9.5.

The state of the stock is summarised in Figure 3.9.6 and Table 3.9.10. The final estimates for the stock are:

F in 2015 (average over ages 4-6) = 0.144
SSB in 2016 (total over ages 3-10+) = 10,451 t

There are currently no reference points for this stock.

Recruitment is estimated to have increased substantially since 2000 resulting in the highest estimated SSB of the time series in 2012. Since then the stock has remained relatively stable at a high level. This increase in stock size means that despite an increase in landings since 2011, fishing mortality remains relatively low.

3.9.6 Comparison with Previous Assessments

The last Scottish scallop assessment report was published in 2012 (Dobby *et al.*, 2012). A comparison between the latest assessment and that given in the 2012 report is presented in Figure 3.9.14. The two assessments show good consistency, in the estimates of fishing mortality and recruitment until the early 2000s. Since 2003 the two assessments show a diverging trend with the most recent assessment showing an increasing SSB to 2010 while the 2012 assessment estimates a declining SSB over this period. The main factor contributing to this difference is the alternative assumptions about the survey data with the earlier assessment treating the survey data as a single survey index while in the most recent assessment it was considered more appropriate to treat the data as three separate time series.

3.9.7 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 Fish 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 since then.

The main uncertainty in the West of Kintyre stock assessment is associated with the estimate of landings being taken from the western half of statistical rectangle 40E4, the eastern half of the rectangle being part of the Clyde assessment area. Vessels are required to report landings at a statistical rectangle level so the allocation of landings to the two components relies on the local fishery office having detailed knowledge of where vessels have been fishing within 40E4. There has been a noticeable decline in the proportion of the landings from 40E4 which have been attributed to the West of Kintyre in recent years and most of the landings are now allocated to the Clyde assessment area. Given the level of VMS derived scallop fishing effort occurring in the two halves of the rectangle (Figure 3.6.16), the current split seems unlikely to be appropriate (although the apparent lack of effort in the eastern half may in part be attributable to under 12 m vessels fishing without VMS). As a result, landings from this area may be underestimated which could result in underestimates of fishing mortality.

Age Composition

Although market sampling levels across this area have generally been good, the age composition data for this stock still appears to be relatively noisy.

Survey Data

The survey provides good coverage of the fishing grounds (as inferred from scallop VMS, Figure 3.6.16) off the east coast of Islay, the southeast of Jura and to the west of the Kintyre peninsula. However, there are areas within the West of Kintyre assessment area where survey coverage is poorer including the area to the northern end of the sound of Jura (where fishing effort is high) and the grounds between southwest of Islay and Northern Ireland where there is a large patch of lower intensity scallop fishing effort.

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 which results in uncertain estimates of recruitment in the final year.

Retrospective Bias

The assessment shows some tendency towards systematic underestimation of SSB (and overestimation of F). However, the direction of bias (underestimating SSB, overestimating F) leads to a conservative stock assessment and any resulting advice is therefore likely to be more precautionary.

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 lower recruitment during the late 1990s, the stocks to the north and east of Scotland (East Coast , North East and Shetland) experienced higher recruitment during the 2000s resulting in increased SSB. More recent recruitment is estimated to be poorer, particularly in the East Coast and North East areas, and SSB also now shows a declining trend. The recent high catches in the East Coast area are reflected in an increase in fishing mortality while fishing mortality in the North East is estimated to be fluctuating without trend in recent years, but with significant uncertainty surrounding the estimates.

To the west of Scotland (North West and West of Kintyre assessment areas), recent good recruitment has resulted in increases in SSB. In both areas fishing mortality has declined since 2000, despite a substantial increase in catches from the West of Kintyre area.

Historical stock trends estimated by the TSA approach show generally good agreement with previous scallop assessments (Dobby et al., 2012). The absolute level of SSB, presented here is not directly comparable with previous assessments as different measures have been used to define these quantities (total live weight in 2016, muscle weight in 2012). At present there are insufficient data from the Clyde, the Irish Sea and Orkney assessment areas to perform analytical assessments or evaluate stock trends.

The stock recruitment plots provided for the five areas assessed using TSA show little evidence of a stock recruitment relationship and for this reason, recruitment is modelled as a random walk. One explanation for this lack of relationship is that the model estimates of SSB (biomass of individuals aged three and above) may not be a good measure of spawning potential either because a proportion of two year old individuals are also likely to be mature but are not included in the model or because SSB does not sufficiently account for the greater reproductive output of larger individuals. Another is that recruitment is largely 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.

4.2 Management Considerations

There are currently no agreed biomass or fishing mortality reference points for Scottish scallop stocks. MSS' comments on 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 and perceptions of how the stock might develop. Recruitment is clearly important to the fishery. In most of the assessment areas, periods of highest landings are associated with good recruitment, which in turn appear to drive upturns in SSB. Successive recruitments appear to be correlated, with high and lows evolving over four to eight years. During periods of low recruitment, there may be a need to reduce fishing mortality (resulting in reduced landings) to enable a stock to rebuild to (or be maintained at) a level that allows for MSY in future.

For the East Coast, North East and Shetland[1] assessment areas, where recruitment and SSB are declining, advice is for no increase in effort and to consider measures to safeguard the spawning stock at a level that will support MSY for future generations.

For the North West and West of Kintyre assessment areas, the prognosis has improved since the last assessments. Recent recruitment has been high or increasing, while fishing mortality has been stable at or below the long term average. Under these circumstances, advice is for no increase in effort.

New Scottish legislation implemented in mid-2017 increases the MLS from 100 mm to 105 mm for UK vessels in all areas around Scotland excluding the Irish Sea and Shetland (The Regulation of Scallop Fishing (Scotland) Order 2017). Although this may result in a short-term reduction in landings, it has the potential to increase the reproductive capacity of stocks (providing that there is no increase in fishing mortality

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

of larger individuals) and landings in the longer term. Measures to restrict effort are in place (limited licences, zonal dredge limits), but there is currently no mechanism for reducing fishing effort or landings which may in future be required in order to manage fishing mortality under an MSY approach.

In the Irish Sea, there is a restrictive licensing scheme and a range of management measures (curfews, area closures) which apply to vessels fishing for king scallops in Manx waters. Recently, the Isle of Man government have expressed concerns about declines in commercial catch per unit effort data for scallops and, in response to high catch rates at the start of the 2016 fishing season, introduced a temporary limit on daily catch rates in Manx waters. Several administrations have interests and responsibilities for scallop fisheries in the Irish Sea and there is a need to bring together data from different sources to develop a more consistent, multilateral approach to the assessment (and management) of stocks in the area. MSS scientists are involved in the ICES Working Group on scallops which could facilitate the improved scientific collaboration required to produce robust stock assessments for this area.

4.3 Reference Points

The lack of a clear stock recruitment relationship is often assumed to preclude the calculation of target reference points based on maximum sustainable yield (MSY). However, ICES have derived MSY reference points based on an approach which uses stochastic projections to account for uncertainty in the stock recruitment model, in addition to random deviations from the model (ICES, 2016). The software which has been developed to conduct these simulations (Eqsim, part of the 'msy' R package) is also able to account for uncertainty in other population parameters such as weights at age and fishery selectivity. Alternatively, reference points based on per recruit analysis are often used as proxies for F_{MSY} (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 (ICES, 2016).

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).

There are clearly a number of options to be explored for the calculation of appropriate reference points for Scottish scallop stocks. The calculation of fishing mortality reference points using the Eqsim software 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 that could potentially be used to derive biomass reference points. However, testing these reference points within a management strategy evaluation framework would be a more time consuming procedure. The development of reference points would enable the provision of fishery advice consistent with MSY principles and for stocks to be assessed in terms of good environmental status as required under the EU Marine Strategy Framework Directive (MSFD) (EC, 2008). It is anticipated that preliminary reference points will available ahead of MSS' next round of assessments.

4.4 Comments on the Quality of the Data and Assessment

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. 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.

The allocation of landings from statistical rectangle 40E4 between the Clyde and West of Kintyre assessment areas remains problematic and is potentially resulting in biased estimates of landings and biases in subsequent stock assessment results. In recent years, the current approach provides a landings split which is at odds with the apparent fishery distribution in the area. The introduction of a new Scottish Government official landings database in 2017 will require the estimation procedure to be modified for 2017 onwards. Potential approaches which are currently being explored, and may provide improved estimates, include making use of VMS data for vessels > 12 m and allocating trip landings on the basis of location of landings harbour.

There are insufficient age composition samples from the Clyde, Irish Sea and Orkney to perform analytic stock assessments. Clyde and Orkney have historically been less important scallop fishery areas and the unpredictable nature of these fisheries can make the acquisition of landings samples particularly difficult. The number of samples from the Clyde has increased in recent years and the resulting data, provided sampling is maintained, could potentially form the basis of an assessment based on commercial catch-at-age data in future years. The Irish Sea is currently the most important of the scallop assessment area 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 is required to improve the basis for assessment and advice in this area.

In other areas for which MSS have conducted analytical assessments, sampling levels tend to be relatively good for the west of Scotland areas (and Shetland) and poorer for the North Sea assessment areas. 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, results. It is unlikely that additional resources will be made available for sampling in the foreseeable future. There are, however, moves within MSS to redesign the shellfish sampling program with a view to implementing a more formal probability based sampling scheme, increasing the likelihood of unbiased estimates and appropriate coverage of stocks.

In their recent report, the ICES Scallop Assessment WG identify scallop ageing as an area of uncertainty and have proposed an international ageing comparison study through a shell exchange. Within MSS, age-reading training is conducted on a regular basis. The general agreement in trends in age composition data from different sources (survey and landings) suggests consistent age reading (although this does not preclude possible bias in the readings). In some areas (particularly the West of Kintyre) the age composition data appear more noisy which could be due to age reading errors. Equally, it could reflect a heterogeneity of the stock or fishery in the area.

The survey data are an integral component of the stock assessments. 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 although in recent years no survey (or only a partial survey) has been completed due to poor weather. It is not clear whether such a high density of stations is required to retain a particular level of precision in the survey abundance index estimates. In recent years a number of stations to the west of Scotland have not been surveyed due to the presence of newly designated marine protected areas (MPAs) and other areas closed to scallop fishing. An analysis of the historical survey data suggested that the survey index was relatively insensitive to the inclusion/exclusion of these survey stations.

The results from previously presented Scottish scallop stock assessments (Dobby, *et al.*, 2012) suggested a mismatch between the survey and catch data which was interpreted by the model as a change in survey catchability over time. The most significant changes appeared to coincide with the changes in survey vessel which had not been accounted for in the work up of the survey index. In the assessments presented this year, the survey data are included as separate indices for each vessel which has resulted in persistent trends in catchability being either estimated as non-significant or zero.

The current stock assessments provide an indication of stock status (and dynamics) in the assessment areas as currently defined. These areas were, however, based on the characteristics of fisheries in the past rather than on the basis of evidence of discrete populations. The population structure of Scottish scallop stocks is not well understood. Scallops are sedentary in nature and only 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. The similar trends in recruitment across the West of Kintyre and North West and also in 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. There is 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. Approaches which combine hydrodynamic and population modelling could provide insights into the nature and extent of connectivity between scallop populations around Scotland and represent a significant area of further work.

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6 Tables

Table 2.1.1: Scottish scallop assessment areas.

Name	Statistical Rectangles	Section
Clyde	39-40 E5; 40 E4 (eastern half)	3.2
East Coast	39-43 E8-F0; 40-41 E6; 40-43 E7; 44 E9-F0	3.3
Irish Sea	35-37 E3-E7; 38 E4-E6	3.4
North East	44 E5-E8; 45 E6-E9; 46 E7-E9; 47 E8-E9	3.5
North West	41-46 E1-E3; 42-46 E4	3.6
Orkney	47 E4; 46-47 E5-E6; 47 E7	3.7
Shetland	48-51 E7-E9	3.8
West of Kintyre	39-40 E2-E3; 39 E4; 40 E4 (western half); 41 E4	3.9

Table 3.1.1: Scottish (UK vessels into Scotland) dredge landings (tonnes).

Year	Clyde	East Coast	Irish Sea	North East	North West	Orkney	Shetland	West of Kintyre	Total
1982	102	5	340	672	3173	42	422	1510	6266
1983	68	0	266	645	2035	29	357	1234	4634
1984	132	0	594	403	2220	22	402	1677	5450
1985	180	0	538	388	1524	4	212	913	3759
1986	76	0	270	559	1437	109	362	688	3501
1987	92	1	415	679	1670	120	311	883	4171
1988	79	0	594	671	1608	35	359	469	3815
1989	31	1	450	894	1581	293	537	577	4364
1990	18	2	451	952	1357	176	447	620	4023
1991	48	540	374	385	1104	124	405	617	3597
1992	23	321	234	1733	1070	26	534	781	4722
1993	75	626	314	1571	976	0	530	1014	5106
1994	182	1813	242	2322	1845	110	603	1073	8190
1995	139	1902	410	3150	1366	214	743	890	8814
1996	110	679	605	3490	2037	214	674	1154	8963
1997	231	715	397	2943	2300	146	932	1360	9024
1998	243	1006	682	1739	2698	163	920	1528	8979
1999	201	1819	1039	1682	1087	291	748	1188	8055
2000	352	726	458	1512	3337	99	338	1630	8452
2001	304	299	732	1736	4132	442	492	1069	9206
2002	473	416	637	738	4261	268	558	1308	8659
2003	508	818	634	1814	3441	175	757	1410	9557
2004	541	2439	751	1958	3163	148	894	1026	10920
2005	415	1571	839	2025	2517	220	720	1021	9328
2006	387	1769	733	1795	1135	117	772	785	7493
2007	300	2593	831	1333	1300	104	858	974	8293
2008	439	1843	894	1385	2201	184	880	1383	9209
2009	451	1528	1450	2155	1318	192	915	1092	9101
2010	528	1757	1461	1267	1134	176	1071	1305	8699
2011	500	828	1233	809	1207	431	911	1276	7195
2012	753	1455	1008	1285	1553	421	1144	2081	9700
2013	572	2238	1034	2767	1813	614	1413	1366	11817
2014	556	1465	1074	1874	1929	277	1005	1528	9708
2015	514	2220	826	1824	1917	379	1080	934	9694

Table 3.1.2: Diver caught landings (tonnes) into Scotland.

Year	Clyde	East Coast	Irish Sea	North East	North West	Orkney	Shetland	West of Kintyre	Total
1982	0	0	0	12	163	7	1	83	266
1983	5	0	0	4	303	38	0	106	456
1984	3	0	0	0	388	98	0	59	548
1985	11	0	0	0	310	71	0	63	455
1986	0	0	0	17	299	35	6	94	451
1987	0	0	0	1	426	46	0	105	578
1988	0	0	0	5	244	49	1	88	387
1989	1	0	0	0	170	74	0	59	304
1990	0	0	0	3	83	57	0	41	184
1991	0	0	0	0	175	70	21	47	313
1992	0	0	0	0	199	87	1	47	334
1993	0	0	0	0	171	36	47	48	302
1994	1	0	0	0	157	92	27	120	397
1995	0	0	0	2	453	222	22	38	737
1996	0	0	0	3	287	150	0	109	549
1997	0	1	0	1	481	139	0	128	750
1998	0	0	0	0	394	176	6	135	711
1999	0	0	0	0	150	162	7	62	381
2000	5	0	0	4	142	162	0	18	331
2001	15	0	0	9	244	126	0	113	507
2002	37	0	0	3	272	117	14	50	493
2003	18	0	0	0	296	113	4	59	490
2004	27	0	0	3	118	87	0	43	278
2005	42	0	0	3	134	172	0	43	394
2006	11	0	0	6	196	100	0	52	365
2007	4	0	0	0	230	80	0	48	362
2008	37	0	0	1	162	89	0	56	345
2009	24	0	0	3	205	101	0	60	393
2010	6	0	0	1	228	125	0	73	433
2011	6	0	0	0	175	140	0	65	386
2012	11	0	0	0	206	133	2	77	429
2013	56	0	0	0	208	125	0	67	456
2014	63	0	0	3	263	164	8	96	598
2015	51	0	0	1	275	213	9	114	663

Table 3.1.3: Total landings (tonnes) from Scottish assessment areas, 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).

Year	Clyde	East Coast	Irish Sea	North East	North West	Orkney	Shetland	West of Kintyre	Total
1982	102	5	2323	684	3336	49	423	1719	**8641**
1983	73	0	2157	649	2338	67	357	1446	**7087**
1984	134	0	3030	403	2608	121	402	1873	**8571**
1985	191	2	3031	388	1834	76	212	1053	**6787**
1986	78	0	2354	576	1735	143	368	844	**6098**
1987	92	1	2734	681	2096	169	311	1066	**7150**
1988	79	0	2433	676	1852	84	360	601	**6085**
1989	32	2	2343	895	1752	367	537	686	**6614**
1990	18	4	1814	956	1447	237	449	714	**5639**
1991	48	560	1675	385	1288	194	426	716	**5292**
1992	23	340	1240	1734	1270	113	535	893	**6148**
1993	77	643	1332	1572	1148	36	577	1146	**6531**
1994	184	1866	1733	2327	2010	202	634	1293	**10249**
1995	139	1953	1744	3155	1820	436	765	1002	**11014**
1996	111	696	2325	3501	2324	365	675	1364	**11361**
1997	231	737	2304	2948	2781	285	932	1606	**11824**
1998	243	1032	2805	1740	3096	340	926	1795	**11977**
1999	201	1866	3330	1683	1255	455	755	1350	**10895**
2000	357	745	2501	1516	3481	260	338	1721	**10919**
2001	319	313	3222	1800	4376	572	496	1249	**12347**
2002	510	478	2800	748	4533	385	572	1453	**11479**
2003	528	830	2768	1814	3758	291	764	1551	**12304**
2004	574	2445	2731	1968	3297	243	895	1174	**13327**
2005	456	1581	2881	2028	2656	393	720	1166	**11881**
2006	400	1805	3009	1829	1356	226	776	908	**10309**
2007	305	2745	3351	1338	1532	203	861	1108	**11443**
2008	481	1937	3912	1395	2407	285	880	1541	**12838**
2009	484	1641	5057	2159	1548	298	915	1386	**13488**
2010	534	1792	5191	1274	1365	314	1072	1478	**13020**
2011	523	865	4575	810	1394	599	911	1383	**11060**
2012	775	1500	4980	1306	1785	590	1151	2428	**14515**
2013	630	2269	5231	2776	2054	798	1418	1715	**16891**
2014	622	1511	5308	1897	2261	472	1024	2386	**15481**
2015	597	2287	5480	1827	2236	639	1099	1412	**15577**

Table 3.2.1: Market sampling levels by assessment area.

	CL		**EC**		**IS**		NE		NW		OR		SH		WK	
	Number	Trips	Number	Trips	Number	Trips	Number	Trips	Number	Trips	Number	Trips	Number	Trips	Number	Trips
1982									4832	19					7424	30
1983									4713	28					4885	27
1984							144	1	6707	36					2390	31
1985	154	1			0	0	158	1	5297	29	0	0	3648	35	9445	52
1986	0	0			551	4	2648	17	7084	34	0	0	6005	59	10166	55
1987	0	0			785	5	849	2	8321	43	0	0	4811	45	6595	31
1988	0	0			1348	6	305	2	2031	12	0	0	2977	29	5606	26
1989	221	1			0	0	1180	7	3740	23	441	2	5946	52	6208	21
1990	0	0			620	3	2202	12	7510	35	249	1	7045	53	13046	52
1991	396	2	2027	12	905	4	4973	23	20467	54	891	4	6120	60	25387	102
1992	245	1	945	6	1261	4	8386	36	25154	67	0	0	6422	58	17573	67
1993	1031	5	3328	14	4678	18	7434	34	19067	65	730	3	8967	73	17161	64
1994	603	3	9855	36	1694	6	10604	43	11742	52	825	4	9304	79	18468	79
1995	519	3	17301	70	3536	14	6042	26	12891	57	1179	7	8965	57	11473	43
1996	979	4	5919	27	1884	8	8330	37	18054	81	1306	8	9863	77	11979	47
1997	2618	12	4049	18	2029	9	7164	30	13043	60	1785	3	8209	61	7693	30
1998	781	4	1759	11	2863	13	3527	20	12005	66	905	6	6527	54	9902	42
1999	657	3	2939	18	1683	9	5447	29	1707	10	1644	7	8279	79	6027	26
2000	621	3	1146	8	1986	11	5946	36	11531	53	812	4	4562	40	9047	42
2001	1143	6	0	0	1302	6	4461	26	16875	83	1564	8	7402	69	8298	40
2002	883	6	340	2	330	2	2042	10	11237	58	664	4	7515	67	6063	30
2003	1141	7	715	3	1354	6	2965	15	9945	47	349	2	9316	83	8425	45
2004	2366	12	2295	11	1273	7	2418	11	3986	19	681	3	8698	77	3918	21
2005	1187	7	1039	5	336	2	1222	7	1172	15	0	0	8778	75	6138	34

2006	261	2	1097	5	986	6	1520	9	2421	13	0	0	11317	101	1373	8
2007	350	3	4260	18	844	4	948	4	2089	9	590	3	11825	110	4392	23
2008	1243	7	3979	17	616	2	4439	21	2919	13	1068	6	8000	94	4617	24
2009	471	3	3100	12	1923	7	1574	7	3599	15	1090	8	5976	59	5949	27
2010	2582	11	1287	6	947	5	1354	6	5142	31	1244	9	6512	65	2124	10
2011	913	5	1227	5	167	1	738	4	2338	16	844	5	6176	65	1890	11
2012	2907	15	2156	11	452	2	2161	10	5782	27	740	6	6795	68	3668	19
2013	2530	13	2848	14	0	0	1567	10	5942	33	626	3	6984	70	4055	24
2014	1740	11	1483	6	319	1	854	4	3805	21	453	2	6428	64	6823	43
2015	2903	14	2636	12	342	2	1251	5	7158	42	759	4	6989	71	5257	31

Table 3.2.2: Clyde. Total catch-at-age numbers (in thousands).

	2	3	4	5	6	7	8	9	10+
2011	0	24	462	1145	761	289	203	87	124
2012	0	5	392	1273	1041	759	490	396	112
2013	0	11	813	1122	657	482	270	118	161
2014	3	137	434	1063	771	458	216	144	167
2015	1	265	536	655	558	457	348	217	194

Table 3.3.1: East Coast. Total catch-at-age numbers (in thousands). No sampling took place in 2001.

	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	NA	NA	NA	NA	NA	NA	NA	NA	NA
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
2011	0	0	87	393	1020	1183	1086	428	316
2012	0	217	498	971	1186	1587	1373	642	809
2013	0	62	775	2113	2148	1888	1803	996	1097
2014	0	71	1254	2346	1782	1092	917	703	434
2015	0	103	1242	3396	2674	1772	1531	1107	1062

Table 3.3.2: East Coast. Mean weights-at-age (total live weight) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1991	0.134	0.164	0.170	0.193	0.213	0.227	0.243	0.249	0.282
1992	0.118	0.134	0.134	0.168	0.187	0.201	0.206	0.227	0.228
1993	0.116	0.131	0.147	0.180	0.212	0.246	0.257	0.266	0.302
1994	0.123	0.128	0.149	0.161	0.197	0.233	0.239	0.254	0.279
1995	0.130	0.137	0.155	0.164	0.177	0.200	0.221	0.232	0.253
1996	0.125	0.129	0.150	0.172	0.190	0.211	0.243	0.278	0.280
1997	0.120	0.131	0.160	0.173	0.189	0.211	0.234	0.253	0.303
1998	0.125	0.150	0.167	0.198	0.221	0.239	0.263	0.283	0.299
1999	0.123	0.160	0.176	0.178	0.190	0.198	0.211	0.223	0.233
2000	0.120	0.136	0.170	0.177	0.201	0.195	0.216	0.228	0.261
2001	0.120	0.146	0.135	0.163	0.173	0.191	0.208	0.218	0.239
2002	0.120	0.140	0.163	0.232	0.227	0.249	0.271	0.277	0.305
2003	0.120	0.130	0.153	0.171	0.203	0.222	0.236	0.250	0.265
2004	0.120	0.114	0.139	0.161	0.179	0.202	0.239	0.250	0.268
2005	0.120	0.107	0.134	0.167	0.197	0.217	0.236	0.254	0.300
2006	0.120	0.127	0.141	0.147	0.170	0.185	0.202	0.220	0.245
2007	0.120	0.134	0.146	0.178	0.217	0.246	0.267	0.266	0.314
2008	0.133	0.154	0.165	0.179	0.207	0.226	0.236	0.263	0.300
2009	0.128	0.141	0.151	0.163	0.187	0.213	0.227	0.257	0.294
2010	0.130	0.127	0.145	0.164	0.179	0.188	0.206	0.214	0.259
2011	0.130	0.127	0.142	0.159	0.173	0.185	0.196	0.225	0.272
2012	0.100	0.137	0.161	0.179	0.193	0.211	0.219	0.233	0.252
2013	0.100	0.133	0.151	0.169	0.191	0.214	0.235	0.249	0.274
2014	0.100	0.121	0.133	0.140	0.163	0.192	0.227	0.255	0.278
2015	0.100	0.130	0.138	0.142	0.160	0.193	0.215	0.225	0.257

Table 3.3.3: Summary of Marine Scotland Science North Sea scallop dredge surveys. Data from greyed out surveys are not used in the assessment.

Vessel	Cruise Dates From	Cruise Dates To	Dredge Type	No. of Dredges	Width (m)	No. of Hauls NE	No. of Hauls EC	No. of Scallops
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 B	3 3	4.5	77	46	6548
R.V. Alba na Mara	27-Jun-08	16-Jul-08	A B	6 6	9	62	32	13110
R.V. Alba na Mara	01-Jul-09	20-Jul-09	A B	6 6	9	56	43	11932
R.V. Alba na Mara	25-Jun-10	14-Jul-10	A B	6 6	9	69	45	13913
R.V. Alba na Mara	22-Jun-11	11-Jul-11	A B	6 6	9	69	44	13716
R.V. Alba na Mara	26-May-12	12-Jun-12	A B	6 6	9	73	45	18424
R.V. Alba na Mara	04-Jul-13	21-Jul-13	A B	6 6	9	74	43	16038
R.V. Alba na Mara	06-Jun-14	24-Jun-14	A B	6 6	9	72	35	15875
R.V. Alba na Mara	20-May-15	08-Jun-15	A B	6 6	9	48	42	16111
R.V. Alba na Mara	19-May-16	07-Jun-16	A B	6 6	9	70	45	13142

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 3.3.4: East Coast. Research-vessel survey data. Catch rates (numbers hour^{-1}metre^{-1}) by age class and year.

Clupea

	2	3	4	5	6	7	8	9	10+
1998	0.000	0.377	0.266	0.488	0.433	2.640	2.329	4.259	4.315
1999	0.098	0.623	0.383	0.317	0.328	2.461	2.177	2.483	2.078
2000	0.596	0.963	0.786	0.215	0.444	0.837	2.548	3.042	3.625
2001	0.029	3.158	1.210	0.653	0.346	0.672	1.709	2.409	2.937
2002	0.019	3.854	6.160	1.163	0.788	0.497	1.275	2.053	2.504
2003	0.000	1.265	5.225	4.367	1.579	0.794	0.960	0.794	3.582
2004	0.203	1.424	2.741	4.979	3.801	0.782	0.589	0.996	3.126
2005	0.107	2.532	2.201	3.136	4.548	3.321	0.838	0.584	3.506
2006	0.000	5.876	3.836	3.192	3.133	3.348	2.489	1.884	2.723
2007	0.018	0.683	3.798	4.836	2.887	2.659	2.095	2.013	3.379

Alba

	2	3	4	5	6	7	8	9	10+
2008	0.000	1.072	4.516	8.401	3.497	2.229	1.597	0.618	3.675
2009	0.000	0.610	2.380	4.070	5.350	3.220	1.990	0.870	4.700
2010	0.000	0.770	2.030	2.910	3.890	4.020	2.250	0.820	4.020
2011	0.000	0.510	1.420	2.990	3.340	4.280	2.890	1.470	3.750
2012	0.000	0.540	3.030	2.520	2.900	4.390	3.960	2.230	9.050
2013	0.000	0.610	1.620	1.990	1.790	2.350	2.640	1.690	7.480
2014	0.000	0.630	3.040	3.040	2.340	3.100	2.670	1.300	7.360
2015	0.000	0.590	5.590	5.530	3.270	2.660	2.080	1.670	11.050
2016	0.010	0.070	1.250	3.150	3.290	2.400	1.400	1.190	7.640

Table 3.3.5: East Coast. TSA final assessment input settings.

Quantity	Setting	Notes
Landings	Ages 3 – 10+	
	Years 1991-2000, 2002-2015	No sampling in 2001
Survey:Clupea	Ages 3-9	
	Years 1998-2007	
Survey:Alba	Ages 3-9	
	Years 2008-2016	
Maturity	100 % for age 3 onwards	
Natural mortality	Fixed at 0.15 for all ages	
Stock weights	Equal to catch weights	
F plateau	Age 8	
Recruitment	Modelled as random walk	
Annual survey CV multiplier	Adjusted according to the number of survey hauls	Allows for greater variability when fewer hauls
Survey age CV multiplier: Clupea	(1.6,1.4,1,1,1,1,1.2)	Allows for greater variability at younger & older ages
Survey age CV multiplier: Alba	(2.2,1,1,1,1,1.2,1.4)	Allows for greater variability at younger & older ages
Recruitment variability	1992, 2001 & 2006: CV multiplier = 3.0	Allows greater variability in these years
F variability	1991 – 2004: CV multiplier = 2.0, 2001: CV multiplier = 3.0	Allows greater variability in F in early years when the fishery is very sporadic
Catch CV multiplier	(2.2,1.5,1,1,1,1,1.4,1.6)	Allows for greater variability at ages 3,4,9 & 10+
Down-weighting single points	Clupea 1998, age 6, cv multiplier = 3	Survey outlier

Table 3.3.6: East Coast. Final TSA run parameter estimates.

Parameter	Notation	Description	2016
Initial fishing mortality	F(3, 1991)	Fishing mortality at age a in year y	0.015
	F(4, 1991)		0.100
	F(8, 1991)		0.351
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0
	σ_U	Persistent changes in selection (age effect in F)	0.035
	σ_V	Transitory changes in the year effect in F	0.283
	σ_Y	Persistent changes in the year effect in F	0
Measurement cv	cv_{catch}	Coefficient of variation of catch-at-age data	0.356
Recruitment		Log mean recruitment at start	2.491
	s_{rw}	Standard deviation of random walk	0.325
	cv_{rec}	Coefficient of variation of recruitment curve	0
Survey selectivities: Clupea	$\Phi_c(3)$	Survey selectivity at age a	0.150
	$\Phi_c(4)$		0.23
	$\Phi_c(5)$		0.324
	$\Phi_c(6)$		0.413
	$\Phi_c(7)$		0.567
	$\Phi_c(8)$		0.967
	$\Phi_c(9)$		1.589
Survey catchability standard deviations: Clupea	$\sigma_{c\Omega}$	Transitory changes in survey catchability	0.107
	$\sigma_{c\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Clupea	$\sigma_{csurvey}$	Coefficient of variation controlling gamma type dispersion	0.164
	$\eta_{csurvey}$	Coefficient of variation controlling poisson type dispersion	0.303
Survey selectivities: Alba	$\Phi_a(3)$	Survey selectivity at age a	0.038
	$\Phi_a(4)$		0.224
	$\Phi_a(5)$		0.322
	$\Phi_a(6)$		0.392
	$\Phi_a(7)$		0.608
	$\Phi_a(8)$		0.693
	$\Phi_a(9)$		0.606
Survey catchability standard deviations: Alba	$\sigma_{a\Omega}$	Transitory changes in survey catchability	0.157
	$\sigma_{a\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Alba	$\sigma_{asurvey}$	Coefficient of variation controlling gamma type dispersion	0.170
	$\eta_{asurvey}$	Coefficient of variation controlling poisson type dispersion	0

[1] Fixed parameter.

Table 3.3.7: East Coast. Estimated population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1991	8.737	3.488	1.982	1.184	1.170	0.779	0.696	2.899
1992	17.561	7.415	2.748	1.510	0.865	0.806	0.495	2.283
1993	17.978	19.846	5.876	2.109	1.115	0.605	0.529	1.817
1994	14.612	15.346	16.126	4.703	1.619	0.833	0.429	1.658
1995	11.521	13.902	12.137	12.013	3.397	1.017	0.477	1.190
1996	5.536	9.615	9.488	7.288	6.412	1.586	0.382	0.630
1997	3.347	4.714	7.738	7.389	5.503	4.663	1.091	0.696
1998	2.363	2.866	3.872	6.082	5.637	4.072	3.259	1.249
1999	3.974	2.322	2.312	2.990	4.525	4.062	2.748	3.037
2000	5.694	3.366	1.779	1.628	1.961	2.844	2.275	3.246
2001	20.541	4.860	2.773	1.401	1.249	1.466	2.040	3.958
2002	24.171	17.653	4.126	2.342	1.145	1.016	1.179	4.827
2003	18.403	20.681	14.636	3.315	1.843	0.880	0.756	4.463
2004	15.971	15.718	17.081	11.634	2.564	1.396	0.636	3.781
2005	21.249	13.319	11.091	10.354	6.319	1.281	0.588	1.867
2006	32.243	18.011	10.435	8.096	7.083	4.169	0.781	1.503
2007	26.258	27.161	13.687	7.185	5.075	4.133	2.204	1.220
2008	21.613	22.146	20.690	9.493	4.606	3.074	2.258	1.888
2009	17.047	18.346	17.546	15.268	6.657	3.121	1.947	2.633
2010	15.014	14.486	14.620	13.118	10.763	4.570	2.018	2.964
2011	15.082	12.739	11.431	10.720	9.028	7.156	2.852	3.113
2012	16.839	12.858	10.341	8.833	7.936	6.540	4.972	4.145
2013	22.036	14.334	10.375	7.849	6.383	5.597	4.403	6.143
2014	22.569	18.657	11.183	7.427	5.228	4.116	3.391	6.396
2015	11.112	19.162	14.808	8.242	5.177	3.543	2.651	6.314
2016	7.086	9.381	14.676	10.108	5.159	3.114	1.979	5.016

Table 3.3.8: East Coast. Standard errors of estimates of population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1991	1.873	0.445	0.348	0.221	0.283	0.201	0.275	1.098
1992	7.384	1.595	0.352	0.272	0.167	0.205	0.138	0.711
1993	2.295	2.010	1.269	0.276	0.207	0.123	0.141	0.483
1994	2.701	1.963	1.666	1.007	0.213	0.154	0.088	0.370
1995	1.817	1.650	1.416	1.219	0.636	0.125	0.079	0.208
1996	0.801	1.138	1.084	0.873	0.782	0.344	0.080	0.143
1997	0.483	0.645	0.903	0.841	0.657	0.581	0.240	0.149
1998	0.785	0.411	0.504	0.702	0.630	0.474	0.409	0.239
1999	0.560	0.318	0.321	0.380	0.512	0.451	0.330	0.411
2000	0.602	0.472	0.223	0.216	0.239	0.326	0.285	0.440
2001	1.588	0.514	0.383	0.177	0.169	0.187	0.258	0.534
2002	2.463	1.363	0.404	0.282	0.130	0.122	0.150	0.631
2003	1.617	2.109	1.125	0.327	0.225	0.101	0.095	0.565
2004	1.279	1.381	1.710	0.922	0.261	0.175	0.078	0.478
2005	1.513	1.074	0.957	1.108	0.647	0.162	0.099	0.317
2006	2.611	1.285	0.839	0.728	0.809	0.453	0.104	0.258
2007	1.721	2.219	1.003	0.623	0.519	0.550	0.296	0.219
2008	1.590	1.444	1.725	0.748	0.436	0.352	0.346	0.315
2009	1.287	1.358	1.168	1.341	0.560	0.313	0.241	0.411
2010	1.123	1.097	1.084	0.915	1.010	0.413	0.222	0.416
2011	1.322	0.956	0.865	0.825	0.680	0.717	0.288	0.408
2012	1.388	1.128	0.775	0.686	0.632	0.518	0.520	0.475
2013	1.831	1.183	0.910	0.608	0.518	0.473	0.385	0.660
2014	2.207	1.554	0.922	0.681	0.428	0.361	0.332	0.716
2015	2.631	1.877	1.244	0.720	0.507	0.317	0.260	0.753
2016	4.924	2.232	1.529	1.011	0.563	0.378	0.234	0.735

Table 3.3.9: East Coast. Estimates of fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1991	0.014	0.090	0.126	0.172	0.233	0.317	0.317	0.317
1992	0.013	0.083	0.119	0.160	0.214	0.290	0.290	0.290
1993	0.009	0.057	0.084	0.112	0.148	0.200	0.200	0.200
1994	0.015	0.101	0.151	0.200	0.261	0.355	0.355	0.355
1995	0.037	0.240	0.365	0.483	0.626	0.855	0.855	0.855
1996	0.010	0.066	0.101	0.134	0.172	0.233	0.233	0.233
1997	0.009	0.059	0.092	0.122	0.156	0.210	0.210	0.210
1998	0.011	0.068	0.107	0.141	0.179	0.242	0.242	0.242
1999	0.019	0.119	0.191	0.250	0.315	0.428	0.428	0.428
2000	0.008	0.051	0.082	0.108	0.135	0.184	0.184	0.184
2001	0.005	0.032	0.054	0.071	0.087	0.119	0.119	0.119
2002	0.006	0.041	0.068	0.090	0.110	0.149	0.149	0.149
2003	0.008	0.048	0.082	0.109	0.132	0.177	0.177	0.177
2004	0.031	0.194	0.340	0.455	0.544	0.720	0.720	0.720
2005	0.015	0.093	0.165	0.224	0.264	0.345	0.345	0.345
2006	0.021	0.129	0.231	0.316	0.372	0.482	0.482	0.482
2007	0.020	0.120	0.217	0.296	0.346	0.445	0.445	0.445
2008	0.014	0.083	0.151	0.207	0.240	0.307	0.307	0.307
2009	0.013	0.078	0.143	0.197	0.227	0.288	0.288	0.288
2010	0.014	0.087	0.163	0.226	0.259	0.324	0.324	0.324
2011	0.010	0.058	0.110	0.152	0.174	0.216	0.216	0.216
2012	0.011	0.066	0.127	0.175	0.199	0.247	0.247	0.247
2013	0.016	0.094	0.184	0.253	0.287	0.352	0.352	0.352
2014	0.013	0.079	0.155	0.214	0.240	0.292	0.292	0.292
2015	0.020	0.118	0.234	0.322	0.363	0.437	0.437	0.437
2016	0.014	0.084	0.167	0.229	0.258	0.311	0.311	0.311

Table 3.3.10: East Coast. 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+
1991	0.004	0.026	0.036	0.049	0.066	0.090	0.090	0.090
1992	0.003	0.023	0.033	0.044	0.059	0.080	0.080	0.080
1993	0.002	0.016	0.024	0.032	0.042	0.057	0.057	0.057
1994	0.004	0.026	0.038	0.050	0.066	0.090	0.090	0.090
1995	0.008	0.050	0.074	0.097	0.127	0.177	0.177	0.177
1996	0.003	0.018	0.027	0.036	0.046	0.063	0.063	0.063
1997	0.003	0.016	0.025	0.032	0.041	0.056	0.056	0.056
1998	0.003	0.018	0.028	0.037	0.047	0.063	0.063	0.063
1999	0.005	0.029	0.044	0.058	0.072	0.098	0.098	0.098
2000	0.002	0.015	0.025	0.032	0.040	0.055	0.055	0.055
2001	0.004	0.025	0.042	0.055	0.068	0.093	0.093	0.093
2002	0.002	0.012	0.019	0.026	0.031	0.042	0.042	0.042
2003	0.002	0.014	0.024	0.031	0.038	0.050	0.050	0.050
2004	0.007	0.043	0.071	0.094	0.111	0.148	0.148	0.148
2005	0.003	0.018	0.030	0.041	0.048	0.063	0.063	0.063
2006	0.004	0.025	0.040	0.055	0.064	0.082	0.082	0.082
2007	0.004	0.023	0.038	0.052	0.060	0.077	0.077	0.077
2008	0.003	0.017	0.028	0.038	0.044	0.056	0.056	0.056
2009	0.003	0.016	0.027	0.037	0.042	0.053	0.053	0.053
2010	0.003	0.018	0.030	0.042	0.048	0.059	0.059	0.059
2011	0.002	0.012	0.021	0.029	0.033	0.041	0.041	0.041
2012	0.003	0.014	0.025	0.034	0.038	0.046	0.046	0.046
2013	0.004	0.020	0.035	0.047	0.053	0.063	0.063	0.063
2014	0.003	0.017	0.031	0.042	0.047	0.055	0.055	0.055
2015	0.005	0.026	0.047	0.064	0.072	0.083	0.083	0.083
2016	0.005	0.026	0.051	0.069	0.078	0.095	0.095	0.095

Table 3.3.11: East Coast. Stock summary from the final TSA run. Catch and Mean F in 2016 are model projections.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1991	545	491	4108	8737	0.129
1992	340	403	5066	17561	0.120
1993	640	467	7892	17978	0.084
1994	1866	1018	8821	14612	0.151
1995	1952	2439	9163	11521	0.363
1996	696	726	7185	5536	0.100
1997	737	735	6660	3347	0.091
1998	1032	945	6658	2363	0.105
1999	1866	1166	5099	3974	0.187
2000	744	437	4347	5694	0.081
2001	313	266	6271	20541	0.052
2002	478	520	10092	24171	0.066
2003	830	686	10721	18403	0.080
2004	2445	2777	10855	15971	0.330
2005	1580	1390	10310	21249	0.161
2006	1806	1878	12244	32243	0.225
2007	2745	2325	14798	26258	0.211
2008	1930	1805	15567	21613	0.147
2009	1640	1779	14304	17047	0.139
2010	1792	1944	12919	15014	0.159
2011	865	1298	11961	15082	0.107
2012	1500	1622	13226	16839	0.123
2013	2269	2254	13803	22036	0.177
2014	1511	1669	12571	22569	0.149
2015	2287	2301	11484	11112	0.225
2016	NA	1593	9728	7086	0.160

Table 3.5.1: 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
2011	0	0	127	452	1222	1181	819	503	166
2012	0	5	343	1540	1870	1488	939	491	783
2013	0	176	1002	2165	2552	2410	2146	1263	1901
2014	0	41	745	3052	2726	1540	1250	916	659
2015	0	16	228	1567	2963	2332	1247	807	1246

Table 3.5.2: North East. Mean weights-at-age (total live weight) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1984	0.106	0.107	0.150	0.157	0.170	0.182	0.202	0.197	0.211
1985	0.100	0.118	0.141	0.143	0.160	0.174	0.189	0.197	0.217
1986	0.112	0.131	0.156	0.180	0.197	0.202	0.210	0.219	0.239
1987	0.106	0.140	0.149	0.171	0.194	0.217	0.239	0.235	0.245
1988	0.106	0.110	0.139	0.164	0.166	0.171	0.163	0.185	0.191
1989	0.112	0.113	0.146	0.153	0.165	0.185	0.201	0.210	0.231
1990	0.131	0.155	0.157	0.173	0.188	0.196	0.205	0.217	0.243
1991	0.133	0.142	0.149	0.178	0.202	0.215	0.224	0.240	0.251
1992	0.121	0.126	0.135	0.157	0.176	0.190	0.207	0.221	0.230
1993	0.114	0.126	0.140	0.169	0.194	0.209	0.222	0.238	0.264
1994	0.123	0.129	0.134	0.146	0.170	0.190	0.198	0.211	0.230
1995	0.103	0.123	0.139	0.152	0.170	0.197	0.205	0.215	0.241
1996	0.124	0.137	0.145	0.158	0.175	0.198	0.214	0.233	0.255
1997	0.114	0.120	0.136	0.148	0.161	0.174	0.186	0.206	0.225
1998	0.114	0.144	0.151	0.165	0.175	0.189	0.207	0.214	0.227
1999	0.100	0.119	0.149	0.162	0.176	0.189	0.200	0.215	0.240
2000	0.118	0.138	0.158	0.192	0.201	0.213	0.224	0.235	0.258
2001	0.100	0.119	0.145	0.165	0.183	0.196	0.204	0.221	0.243
2002	0.106	0.131	0.143	0.168	0.195	0.211	0.216	0.227	0.246
2003	0.109	0.114	0.137	0.152	0.162	0.178	0.192	0.211	0.219
2004	0.129	0.128	0.145	0.169	0.181	0.193	0.206	0.207	0.229
2005	0.093	0.127	0.139	0.183	0.202	0.208	0.218	0.220	0.261
2006	0.111	0.136	0.138	0.163	0.182	0.198	0.210	0.220	0.257
2007	0.111	0.130	0.146	0.168	0.179	0.211	0.235	0.253	0.285
2008	0.152	0.173	0.152	0.160	0.186	0.217	0.237	0.261	0.292
2009	0.127	0.138	0.157	0.173	0.198	0.209	0.228	0.228	0.255
2010	0.139	0.149	0.155	0.158	0.171	0.188	0.209	0.232	0.251
2011	0.139	0.149	0.144	0.150	0.163	0.178	0.199	0.219	0.255
2012	0.139	0.111	0.132	0.142	0.159	0.178	0.199	0.211	0.243
2013	0.139	0.133	0.146	0.160	0.182	0.205	0.230	0.254	0.255
2014	0.139	0.135	0.140	0.145	0.161	0.190	0.197	0.219	0.251
2015	0.139	0.129	0.138	0.140	0.158	0.176	0.188	0.221	0.226

Table 3.5.3: North East. Research-vessel survey data. Catch rates (numbers hour^{-1} metre^{-1}) by age class and year.

Clupea

	2	3	4	5	6	7	8	9	10+
1997	0.109	0.995	2.332	3.747	6.002	7.409	4.338	1.314	2.457
1998	0.121	1.281	1.324	1.767	1.585	3.182	4.390	4.135	3.631
1999	0.081	2.408	2.609	1.562	1.296	2.934	3.477	3.444	3.363
2000	0.096	2.774	4.929	2.175	1.205	1.852	2.519	2.774	2.409
2001	0.017	1.669	4.034	3.854	1.049	1.658	2.173	2.115	2.579
2002	0.041	4.397	7.120	4.974	2.219	1.505	1.871	2.160	2.164
2003	0.106	1.059	5.831	8.321	2.853	3.559	1.364	0.812	4.434
2004	0.466	1.620	2.642	5.229	4.052	2.116	1.052	1.100	2.456
2005	0.155	2.499	2.774	2.909	4.662	4.036	2.093	1.422	1.763
2006	0.005	3.342	4.996	4.501	3.527	4.461	3.092	2.653	3.507
2007	0.038	0.933	4.203	4.306	3.173	2.736	2.299	1.813	2.579

Alba

	2	3	4	5	6	7	8	9	10+
2008	0.053	1.426	5.391	7.577	4.518	3.501	2.644	1.284	3.942
2009	0.030	1.910	3.540	5.780	5.360	3.450	2.530	1.160	5.550
2010	0.010	1.840	3.470	5.460	4.840	4.280	2.560	0.850	4.650
2011	0.010	1.230	4.170	5.600	4.740	5.190	3.170	1.480	5.100
2012	0.010	0.800	5.350	5.810	4.650	5.370	4.040	2.100	6.680
2013	0.010	0.720	5.560	6.240	3.540	3.550	2.930	1.760	8.660
2014	0.010	0.980	4.770	8.340	5.940	4.460	2.920	1.340	5.420
2015	0.000	0.490	6.240	7.630	8.180	5.700	3.020	1.490	8.750
2016	0.000	0.100	2.050	4.400	5.980	5.780	3.010	1.580	5.440

Table 3.5.4: North East. TSA final assessment input settings.

Quantity	Setting	Notes
Landings	Ages 3 – 10+ Years 1984-2015	
Survey:Clupea	Ages 3-9 Years 1997-2007	
Survey:Alba	Ages 3-9 Years 2008-2016	
Maturity	100 % for age 3 onwards	
Natural mortality	Fixed at 0.15 for all ages	
Stock weights	Equal to catch weights	
F plateau	Age 8	
Recruitment	Modelled as random walk	
Annual survey CV multiplier	Adjusted according to the number of survey hauls	Allows for greater variability when fewer hauls
Survey age CV multiplier: Clupea	(1.4,1.2,1,1,1,1,1.2)	Allows for greater variability at younger & older ages
Survey age CV multiplier: Alba	(2.2,1,1,1,1,1.2,1.5)	Allows for greater variability at younger & older ages
Recruitment variability	1990-1997: CV multiplier = 3.0	Allows greater variability to capture big increase in these years
Catch CV multiplier	(1.8,1.2,1,1,1,1,1,1.3)	Allows for greater variability at ages 3,4 & 10+

Table 3.5.5: North East. Final TSA run parameter estimates.

Parameter	Notation	Description	2016
Initial fishing mortality	F(3, 1984)	Fishing mortality at age a in year y	0.005
	F(4, 1984)		0.026
	F(8, 1984)		0.110
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0
	σ_U	Persistent changes in selection (age effect in F)	0.048
	σ_V	Transitory changes in the year effect in F	0.324
	σ_Y	Persistent changes in the year effect in F	0.257
Measurement cv	cv_{catch}	Coefficient of variation of catch-at-age data	0.385
Recruitment		Log mean recruitment at start	2.607
	s_{rw}	Standard deviation of random walk	0.310
	cv_{rec}	Coefficient of variation of recruitment curve	0
Survey selectivities: Clupea	$\Phi_c(3)$	Survey selectivity at age a	0.161
	Φ_c (4)		0.372
	Φ_c (5)		0.53
	Φ_c (6)		0.606
	Φ_c (7)		0.83
	Φ_c (8)		1.094
	Φ_c (9)		1.355
Survey catchability standard deviations: Clupea	$\sigma_{c\Omega}$	Transitory changes in survey catchability	0.102
	$\sigma_{c\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Clupea	$\sigma_{csurvey}$	Coefficient of variation controlling gamma type dispersion	0.359
	$\eta_{csurvey}$	Coefficient of variation controlling poisson type dispersion	0.006
Survey selectivities: Alba	$\Phi_a(3)$	Survey selectivity at age a	0.071
	Φ_a (4)		0.337
	Φ_a (5)		0.562
	Φ_a (6)		0.650
	Φ_a (7)		0.851
	Φ_a (8)		0.870
	Φ_a (9)		0.668
Survey catchability standard deviations: Alba	$\sigma_{a\Omega}$	Transitory changes in survey catchability	0.114
	$\sigma_{a\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Alba	$\sigma_{asurvey}$	Coefficient of variation controlling gamma type dispersion	0
	$\eta_{asurvey}$	Coefficient of variation controlling poisson type dispersion	0.278

[1] Fixed parameter.

Table 3.5.6: North East. Estimated population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1984	4.971	4.915	4.561	5.264	6.371	6.000	4.618	4.714
1985	5.452	4.269	4.148	3.814	4.355	5.182	4.767	7.415
1986	7.239	5.048	3.614	3.466	3.147	3.525	4.109	9.652
1987	6.846	6.198	4.678	3.663	2.792	2.448	2.671	10.435
1988	4.451	5.849	5.127	3.780	2.891	2.105	1.778	9.526
1989	4.421	3.802	4.812	4.095	2.967	2.158	1.509	8.121
1990	14.870	5.671	3.036	3.606	2.947	2.000	1.354	6.118
1991	23.149	12.623	4.561	2.260	2.597	2.002	1.293	4.859
1992	38.280	19.774	10.405	3.669	1.741	1.937	1.458	4.524
1993	41.539	34.418	15.105	7.055	2.395	1.069	1.087	3.358
1994	37.937	35.286	27.483	11.133	4.954	1.615	0.701	2.902
1995	22.627	31.778	27.238	19.124	7.357	3.035	0.944	2.123
1996	14.867	19.048	24.034	18.159	11.871	4.225	1.607	1.635
1997	7.806	10.748	14.394	16.014	11.198	6.537	2.123	1.647
1998	7.525	6.512	8.265	9.814	10.160	6.473	3.467	2.015
1999	10.410	6.384	5.173	6.021	6.784	6.573	3.935	3.351
2000	14.423	8.824	5.050	3.735	4.126	4.350	3.958	4.418
2001	17.452	12.281	7.114	3.727	2.614	2.738	2.740	5.280
2002	18.358	14.876	9.985	5.377	2.695	1.800	1.813	5.311
2003	17.421	15.679	12.284	7.810	4.079	1.974	1.282	5.090
2004	13.047	14.709	11.942	7.999	4.615	2.153	0.967	3.123
2005	14.990	11.072	11.662	8.458	5.306	2.827	1.251	2.376
2006	19.527	12.656	8.550	7.850	5.244	2.973	1.480	1.908
2007	19.740	16.557	10.025	6.099	5.245	3.242	1.744	1.997
2008	17.863	16.815	13.428	7.495	4.353	3.531	2.103	2.434
2009	16.734	15.235	13.709	10.116	5.398	2.980	2.337	3.008
2010	17.410	14.247	12.235	9.902	6.852	3.439	1.815	3.263
2011	20.785	14.893	11.785	9.413	7.282	4.838	2.363	3.496
2012	23.227	17.776	12.414	9.270	7.121	5.330	3.463	4.200
2013	18.706	19.832	14.683	9.599	6.829	5.045	3.681	5.293
2014	15.377	15.869	15.833	10.389	6.183	4.080	2.862	5.110
2015	7.993	13.107	12.961	11.877	7.288	4.101	2.610	5.109
2016	5.244	6.815	10.723	9.736	8.348	4.841	2.628	4.956

Table 3.5.7: North East. Standard errors of estimates of population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1984	1.572	0.673	0.610	0.968	1.418	1.343	1.180	1.561
1985	1.470	1.349	0.570	0.513	0.806	1.162	1.075	1.611
1986	1.568	1.164	1.140	0.480	0.429	0.667	0.941	1.755
1987	1.372	1.341	0.781	0.415	0.393	0.349	0.523	1.813
1988	1.208	1.172	1.113	0.644	0.353	0.314	0.279	1.678
1989	2.232	1.033	0.973	0.917	0.519	0.284	0.245	1.463
1990	2.544	1.123	0.832	0.778	0.718	0.393	0.221	1.206
1991	4.612	2.168	0.918	0.670	0.618	0.539	0.287	1.002
1992	7.853	3.947	1.817	0.763	0.551	0.498	0.423	0.952
1993	4.905	4.880	3.056	1.364	0.542	0.354	0.307	0.799
1994	4.523	4.166	3.945	2.403	1.052	0.397	0.247	0.734
1995	2.701	3.573	3.196	2.875	1.640	0.675	0.233	0.541
1996	4.759	2.258	2.661	2.191	1.891	0.967	0.384	0.419
1997	0.862	1.283	1.667	1.785	1.435	1.148	0.544	0.440
1998	0.766	0.632	0.977	1.165	1.195	0.872	0.644	0.498
1999	1.030	0.651	0.506	0.723	0.833	0.816	0.573	0.665
2000	1.306	0.872	0.511	0.364	0.492	0.542	0.528	0.727
2001	1.950	1.107	0.679	0.364	0.250	0.319	0.347	0.760
2002	1.935	1.656	0.880	0.511	0.263	0.177	0.221	0.730
2003	1.756	1.649	1.342	0.698	0.396	0.200	0.134	0.674
2004	1.210	1.472	1.193	0.852	0.450	0.235	0.117	0.454
2005	1.175	1.023	1.140	0.855	0.579	0.301	0.150	0.366
2006	1.300	0.990	0.767	0.765	0.550	0.349	0.183	0.304
2007	1.288	1.104	0.779	0.549	0.527	0.365	0.229	0.325
2008	1.205	1.100	0.895	0.592	0.402	0.369	0.260	0.384
2009	1.221	1.029	0.897	0.693	0.443	0.290	0.268	0.446
2010	1.312	1.041	0.814	0.639	0.492	0.302	0.205	0.472
2011	1.410	1.123	0.845	0.615	0.475	0.360	0.223	0.475
2012	1.398	1.207	0.929	0.667	0.477	0.367	0.282	0.502
2013	1.376	1.196	1.003	0.734	0.517	0.375	0.294	0.583
2014	1.596	1.170	0.961	0.731	0.494	0.356	0.277	0.632
2015	1.730	1.364	0.965	0.782	0.563	0.362	0.262	0.685
2016	2.812	1.479	1.147	0.804	0.678	0.467	0.287	0.734

Table 3.5.8: North East. Estimates of fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1984	0.004	0.019	0.027	0.039	0.058	0.081	0.081	0.081
1985	0.004	0.020	0.030	0.042	0.063	0.085	0.085	0.085
1986	0.006	0.031	0.048	0.066	0.101	0.133	0.133	0.133
1987	0.008	0.041	0.065	0.088	0.133	0.173	0.173	0.173
1988	0.009	0.046	0.074	0.098	0.145	0.189	0.189	0.189
1989	0.015	0.078	0.131	0.172	0.251	0.324	0.324	0.324
1990	0.014	0.073	0.128	0.166	0.236	0.301	0.301	0.301
1991	0.008	0.042	0.076	0.099	0.137	0.173	0.173	0.173
1992	0.022	0.121	0.227	0.293	0.394	0.493	0.493	0.493
1993	0.014	0.078	0.151	0.194	0.258	0.319	0.319	0.319
1994	0.019	0.107	0.216	0.276	0.363	0.445	0.445	0.445
1995	0.023	0.127	0.259	0.335	0.437	0.534	0.534	0.534
1996	0.023	0.126	0.258	0.338	0.443	0.540	0.540	0.540
1997	0.020	0.114	0.236	0.309	0.404	0.492	0.492	0.492
1998	0.014	0.081	0.167	0.219	0.286	0.350	0.350	0.350
1999	0.014	0.082	0.171	0.224	0.291	0.355	0.355	0.355
2000	0.013	0.073	0.153	0.199	0.258	0.314	0.314	0.314
2001	0.011	0.061	0.131	0.171	0.219	0.265	0.265	0.265
2002	0.007	0.043	0.094	0.124	0.159	0.188	0.188	0.188
2003	0.022	0.126	0.286	0.379	0.490	0.567	0.567	0.567
2004	0.015	0.086	0.196	0.262	0.341	0.395	0.395	0.395
2005	0.018	0.105	0.243	0.325	0.428	0.499	0.499	0.499
2006	0.014	0.080	0.188	0.252	0.331	0.386	0.386	0.386
2007	0.010	0.059	0.141	0.189	0.246	0.284	0.284	0.284
2008	0.010	0.054	0.132	0.179	0.229	0.263	0.263	0.263
2009	0.012	0.070	0.175	0.239	0.301	0.346	0.346	0.346
2010	0.008	0.045	0.113	0.158	0.199	0.227	0.227	0.227
2011	0.006	0.035	0.091	0.129	0.162	0.185	0.185	0.185
2012	0.007	0.041	0.107	0.155	0.194	0.221	0.221	0.221
2013	0.014	0.074	0.195	0.288	0.363	0.417	0.417	0.417
2014	0.010	0.052	0.139	0.207	0.262	0.300	0.300	0.300
2015	0.010	0.052	0.138	0.205	0.263	0.299	0.299	0.299
2016	0.010	0.052	0.138	0.205	0.263	0.301	0.301	0.301

Table 3.5.9: 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	0.001	0.004	0.007	0.009	0.014	0.019	0.019	0.019
1985	0.001	0.005	0.007	0.010	0.016	0.021	0.021	0.021
1986	0.002	0.008	0.012	0.017	0.025	0.033	0.033	0.033
1987	0.002	0.011	0.016	0.023	0.034	0.044	0.044	0.044
1988	0.002	0.011	0.018	0.024	0.036	0.046	0.046	0.046
1989	0.004	0.019	0.031	0.041	0.060	0.077	0.077	0.077
1990	0.003	0.018	0.030	0.039	0.056	0.071	0.071	0.071
1991	0.002	0.010	0.019	0.024	0.033	0.042	0.042	0.042
1992	0.005	0.027	0.050	0.064	0.086	0.107	0.107	0.107
1993	0.004	0.018	0.034	0.044	0.058	0.072	0.072	0.072
1994	0.005	0.024	0.047	0.060	0.078	0.096	0.096	0.096
1995	0.005	0.027	0.053	0.069	0.089	0.111	0.111	0.111
1996	0.005	0.027	0.052	0.068	0.089	0.109	0.109	0.109
1997	0.005	0.025	0.048	0.062	0.081	0.099	0.099	0.099
1998	0.004	0.018	0.036	0.047	0.061	0.074	0.074	0.074
1999	0.004	0.018	0.037	0.048	0.062	0.075	0.075	0.075
2000	0.003	0.016	0.033	0.043	0.055	0.066	0.066	0.066
2001	0.003	0.014	0.029	0.038	0.049	0.058	0.058	0.058
2002	0.002	0.011	0.022	0.029	0.038	0.043	0.043	0.043
2003	0.005	0.025	0.053	0.069	0.088	0.100	0.100	0.100
2004	0.004	0.019	0.041	0.054	0.070	0.081	0.081	0.081
2005	0.005	0.022	0.049	0.064	0.084	0.097	0.097	0.097
2006	0.004	0.018	0.040	0.053	0.069	0.080	0.080	0.080
2007	0.003	0.014	0.031	0.042	0.054	0.062	0.062	0.062
2008	0.003	0.013	0.030	0.040	0.051	0.058	0.058	0.058
2009	0.003	0.016	0.037	0.050	0.063	0.073	0.073	0.073
2010	0.002	0.011	0.026	0.035	0.045	0.050	0.050	0.050
2011	0.002	0.009	0.021	0.030	0.038	0.042	0.042	0.042
2012	0.002	0.010	0.025	0.036	0.045	0.050	0.050	0.050
2013	0.004	0.017	0.042	0.059	0.074	0.083	0.083	0.083
2014	0.003	0.013	0.032	0.047	0.059	0.066	0.066	0.066
2015	0.003	0.014	0.034	0.050	0.064	0.070	0.070	0.070
2016	0.005	0.025	0.064	0.094	0.121	0.139	0.139	0.139

Table 3.5.10: North East. Stock summary from the final TSA run. Catch estimate and Mean F in 2016 are model forecasts.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1984	377	345	7153	4971	0.028
1985	366	357	6726	5452	0.030
1986	628	602	7654	7239	0.049
1987	616	759	7767	6846	0.065
1988	723	600	5755	4451	0.072
1989	859	1007	5640	4421	0.127
1990	945	874	7165	14870	0.122
1991	387	542	8976	23149	0.073
1992	1827	1572	11853	38280	0.214
1993	1565	1406	15874	41539	0.141
1994	2588	2315	17556	37937	0.200
1995	3413	3273	17376	22627	0.240
1996	3445	3437	15830	14867	0.241
1997	2682	2550	11064	7806	0.220
1998	1563	1734	9604	7525	0.156
1999	1772	1528	8332	10410	0.159
2000	1828	1313	9022	14423	0.142
2001	1336	973	8673	17452	0.121
2002	781	763	9933	18358	0.087
2003	2053	2051	9746	17421	0.264
2004	1748	1481	9530	13047	0.181
2005	2102	1953	9883	14990	0.224
2006	1615	1377	9706	19527	0.173
2007	1334	1163	10624	19740	0.130
2008	1427	1241	12229	17863	0.122
2009	2155	1740	12184	16734	0.161
2010	1274	1114	11668	17410	0.105
2011	810	951	12204	20785	0.085
2012	1306	1190	12227	23227	0.101
2013	2776	2507	14329	18706	0.186
2014	1897	1593	12149	15377	0.133
2015	1827	1504	10314	7993	0.132
2016	NA	1515	9275	5244	0.132

Table 3.6.1: 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	12	524	885	1481	1621	1565	1077	638	416
2010	0	148	1069	1364	1244	1144	953	520	588
2011	19	438	1200	1422	1269	1158	1110	503	543
2012	0	38	795	2959	2356	1546	1231	672	694
2013	0	72	1173	1899	2584	1774	1529	697	1436
2014	0	3	845	2620	3057	2567	1249	649	1032
2015	0	400	653	1706	2536	2358	1499	985	1796

Table 3.6.2: North West. Mean weights-at-age (total live weight) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1982	0.096	0.120	0.140	0.168	0.179	0.194	0.213	0.224	0.246
1983	0.106	0.121	0.135	0.147	0.153	0.174	0.180	0.199	0.215
1984	0.127	0.139	0.153	0.167	0.178	0.191	0.194	0.207	0.243
1985	0.112	0.129	0.148	0.168	0.185	0.189	0.195	0.209	0.226
1986	0.105	0.124	0.146	0.152	0.163	0.176	0.186	0.196	0.210
1987	0.107	0.120	0.136	0.149	0.157	0.167	0.167	0.173	0.192
1988	0.125	0.134	0.148	0.160	0.167	0.176	0.184	0.185	0.197
1989	0.124	0.129	0.146	0.157	0.164	0.173	0.180	0.189	0.202
1990	0.115	0.135	0.154	0.175	0.165	0.175	0.178	0.188	0.213
1991	0.112	0.126	0.142	0.162	0.174	0.191	0.200	0.212	0.213
1992	0.124	0.134	0.150	0.164	0.177	0.188	0.189	0.194	0.203
1993	0.130	0.136	0.153	0.169	0.181	0.192	0.204	0.212	0.223
1994	0.127	0.133	0.150	0.173	0.193	0.207	0.212	0.221	0.235
1995	0.128	0.143	0.152	0.164	0.179	0.196	0.204	0.213	0.232
1996	0.115	0.132	0.151	0.169	0.181	0.193	0.198	0.198	0.207
1997	0.125	0.139	0.145	0.163	0.180	0.197	0.205	0.216	0.236
1998	0.129	0.140	0.151	0.170	0.185	0.195	0.194	0.199	0.217
1999	0.111	0.130	0.157	0.177	0.195	0.212	0.217	0.222	0.244
2000	0.120	0.140	0.154	0.175	0.191	0.200	0.210	0.218	0.220
2001	0.113	0.131	0.149	0.164	0.178	0.194	0.199	0.205	0.219
2002	0.103	0.133	0.150	0.167	0.189	0.204	0.213	0.223	0.233
2003	0.115	0.133	0.143	0.159	0.178	0.196	0.209	0.216	0.228
2004	0.107	0.127	0.146	0.166	0.182	0.196	0.201	0.215	0.223
2005	0.107	0.128	0.147	0.172	0.187	0.200	0.213	0.229	0.223
2006	0.109	0.133	0.143	0.158	0.172	0.184	0.197	0.207	0.227
2007	0.107	0.127	0.140	0.155	0.160	0.173	0.194	0.193	0.190
2008	0.107	0.134	0.158	0.178	0.200	0.217	0.241	0.265	0.258
2009	0.135	0.135	0.153	0.172	0.187	0.198	0.212	0.223	0.249
2010	0.135	0.135	0.150	0.168	0.185	0.204	0.220	0.241	0.269
2011	0.133	0.148	0.158	0.159	0.173	0.189	0.205	0.222	0.243
2012	0.133	0.131	0.135	0.151	0.165	0.186	0.199	0.210	0.235
2013	0.133	0.131	0.148	0.161	0.170	0.188	0.201	0.216	0.234
2014	0.133	0.138	0.143	0.155	0.173	0.193	0.227	0.244	0.260
2015	0.100	0.131	0.150	0.157	0.170	0.183	0.202	0.215	0.227

Table 3.6.3: Summary of Marine Scotland Science West Coast scallop dredge surveys. 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
R.V. Alba na Mara	04-Apr-11	23-Apr-11	A B	6 6	9	22	65	14944

R.V. Alba na Mara	09-Apr-12	23-Apr-12	A B	6 6	9	21	54	14905
R.V. Alba na Mara	03-Apr-13	22-Apr-13	A B	6 6	9	18	61	14855
R.V. Alba na Mara	04-Apr-14	23-Apr-14	A B	6 6	9	15	53	10835
R.V. Alba na Mara	29-Mar-15	17-Apr-15	A B	6 6	9	16	55	13357
R.V. Alba na Mara	28-Mar-16	15-Apr-16	A B	6 6	9	17	56	13345

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 3.6.4: North West. Research-vessel survey data. Catch rates (numbers hour^{-1}metre^{-1}) by age class and year.

Aora

	2	3	4	5	6	7	8	9	10+
1993	0.118	6.419	12.511	9.196	5.894	3.667	2.529	3.067	8.838
1994	0.052	3.694	9.164	11.070	7.548	4.358	2.769	2.166	9.943
1995	0.134	5.238	7.702	10.369	8.019	4.299	2.845	2.303	5.609
1996	0.129	3.472	7.674	7.652	8.086	6.195	2.819	1.608	6.527
1997	0.070	2.844	9.430	8.748	6.458	5.741	3.596	2.127	5.088
1998	0.220	7.525	8.335	8.502	5.836	4.947	4.194	3.012	5.260
1999	0.116	4.596	9.632	6.215	5.233	4.155	3.831	3.092	4.494
2000	0.082	9.722	11.323	9.141	4.654	4.715	3.467	3.200	4.511
2001	0.366	6.224	14.291	8.260	5.006	2.936	2.700	1.588	2.883
2002	0.021	6.288	9.693	13.824	5.759	3.443	2.637	2.018	2.760

Aora II

	2	3	4	5	6	7	8	9	10+
2003	0.898	7.885	10.475	9.346	7.926	3.756	2.264	1.865	4.215
2004	0.610	4.820	7.877	8.619	7.580	5.450	2.845	2.130	4.143
2005	0.024	2.272	5.046	6.377	7.242	6.019	4.795	3.682	5.774
2006	0.022	2.441	6.426	6.424	6.508	5.586	4.390	3.350	4.824
2007	0.009	0.856	3.797	4.054	4.662	4.382	3.666	2.932	4.400

Alba na Mara

	2	3	4	5	6	7	8	9	10+
2008	0.015	0.290	1.328	3.688	4.373	4.376	3.451	2.683	7.959
2009	0.030	0.780	2.720	3.890	4.420	3.570	3.120	1.570	7.930
2010	0.010	1.310	3.470	3.320	3.170	2.760	1.970	0.810	7.280
2011	0.000	0.830	4.930	6.330	4.060	4.240	3.100	1.810	7.760
2012	0.000	1.310	6.370	9.750	5.400	4.020	3.450	1.840	9.110
2013	0.040	1.380	7.090	7.940	5.850	4.470	3.480	1.950	5.710
2014	0.010	0.680	4.600	6.670	5.630	4.280	3.020	1.630	5.920
2015	0.050	1.390	5.280	6.560	6.580	5.160	2.900	1.760	6.020
2016	0.020	1.130	8.030	5.840	5.430	5.300	3.470	2.060	6.540

Table 3.6.5: North West. TSA final assessment input settings.

Quantity	Setting	Notes
Landings	Ages 3 – 10+ Years 1982-2007, 2009-2015	2008 data not included due to strange age composition which has large influence on surrounding estimates
Survey:Aora	Ages 3-9 Years 1995-2002	1993 & 1994 Aora survey indices omitted – have much higher catchability than the rest of the time series.
Survey: Aora II	Ages 3-9 Years 2003-2007	
Survey:Alba	Ages 3-9 Years 2008-2016	
Maturity	100 % for age 3 onwards	
Natural mortality	Fixed at 0.15 for all ages	
Stock weights	Equal to catch weights	
F plateau	Age 8	
Recruitment	Modelled as random walk	
Annual survey CV multiplier	Adjusted according to the number of survey hauls	Allows for greater variability when fewer hauls
Survey age CV multiplier: Aora	(3.0,1.5,1,1,1,1,1.8)	Allows for greater variability at younger & older ages
Survey age CV multiplier: Aora II	(3.0,1.5,1,1,1,1,1.8)	Allows for greater variability at younger & older ages
Survey age CV multiplier: Alba	(1.4,1.2,1,1,1,1,1.2)	Allows for greater variability at younger & older ages
F variability	1999: CV multiplier = 3.0	Allows greater variability in F in this year – sudden decrease in landings associated with ASP/PSP closures
Catch CV multiplier	(2.6,1.2,1.2,1,1,1,1.2,1.6)	Allows for greater variability at ages 3,4,5,9 & 10+
Down-weighting single points	Alba 2008, age 4, cv multiplier = 3	Survey outlier

Table 3.6.6: North West. Final TSA run parameter estimates.

Parameter	Notation	Description	2016
Initial fishing mortality	F(3, 1982)	Fishing mortality at age a in year y	0.054
	F(4, 1982)		0.114
	F(8, 1982)		0.256
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0
	σ_U	Persistent changes in selection (age effect in F)	0.078
	σ_V	Transitory changes in the year effect in F	0.106
	σ_Y	Persistent changes in the year effect in F	0.126
Measurement cv	cv_{catch}	Coefficient of variation of catch-at-age data	0.156
Recruitment		Log mean recruitment at start	3.275
	s_{rw}	Standard deviation of random walk	0.179
	cv_{rec}	Coefficient of variation of recruitment curve	0
Survey selectivities: Aora	$\Phi_{a1}(3)$	Survey selectivity at age a	0.210
	$\Phi_{a1}(4)$		0.440
	$\Phi_{a1}(5)$		0.570
	$\Phi_{a1}(6)$		0.572
	$\Phi_{a1}(7)$		0.636
	$\Phi_{a1}(8)$		0.745
	$\Phi_{a1}(9)$		0.912
Survey catchability standard deviations: Aora	$\sigma_{a1\Omega}$	Transitory changes in survey catchability	0.060
	$\sigma_{a1\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Aora	$\sigma_{a1survey}$	Coefficient of variation controlling gamma type dispersion	0.098
	$\eta_{a1survey}$	Coefficient of variation controlling poisson type dispersion	0.127
Survey selectivities: Aora II	$\Phi_{a2}(3)$	Survey selectivity at age a	0.218
	$\Phi_{a2}(4)$		0.423
	$\Phi_{a2}(5)$		0.539
	$\Phi_{a2}(6)$		0.711
	$\Phi_{a2}(7)$		0.849
	$\Phi_{a2}(8)$		1.084
	$\Phi_{a2}(9)$		1.620
Survey catchability standard deviations: Aora II	$\sigma_{a2\Omega}$	Transitory changes in survey catchability	0.083
	$\sigma_{a2\beta}$	Persistent changes in survey catchability	0[1]

[1]Fixed parameter.

Survey measurement coefficients of variation: Aora II	$\sigma_{a2survey}$	Coefficient of variation controlling gamma type dispersion	0
	$\eta_{a2survey}$	Coefficient of variation controlling poisson type dispersion	0.235
Survey selectivities: Alba	$\Phi_a(3)$	Survey selectivity at age a	0.039
	Φ_a (4)		0.253
	Φ_a (5)		0.420
	Φ_a (6)		0.500
	Φ_a (7)		0.660
	Φ_a (8)		0.794
	Φ_a (9)		0.734
Survey catchability standard deviations: Alba	$\sigma_{a\Omega}$	Transitory changes in survey catchability	0.124
	$\sigma_{a\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Alba	$\sigma_{asurvey}$	Coefficient of variation controlling gamma type dispersion	0.064
	$\eta_{asurvey}$	Coefficient of variation controlling poisson type dispersion	0.218

[1] Fixed parameter.

Table 3.6.7: North West. Estimated population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	22.737	21.535	20.746	18.314	14.715	11.031	5.542	12.963
1983	20.559	18.603	16.694	15.701	13.353	10.372	7.412	12.433
1984	18.576	16.931	14.648	12.887	11.639	9.620	7.100	13.586
1985	16.277	15.279	13.211	11.228	9.483	8.367	6.609	14.219
1986	14.993	13.534	12.128	10.325	8.507	7.056	5.986	14.895
1987	13.538	12.459	10.748	9.402	7.727	6.291	4.917	14.564
1988	10.417	11.145	9.681	8.084	6.744	5.490	4.062	12.596
1989	12.333	8.587	8.671	7.253	5.830	4.761	3.568	10.854
1990	17.261	10.141	6.537	6.252	4.961	3.845	2.985	9.110
1991	20.918	14.308	7.927	4.868	4.442	3.423	2.555	8.094
1992	30.236	17.422	11.164	5.960	3.499	3.181	2.409	7.490
1993	31.128	25.173	13.760	8.354	4.319	2.541	2.265	7.082
1994	26.761	25.977	19.885	10.423	6.123	3.159	1.829	6.713
1995	26.921	22.380	20.387	14.662	7.416	4.376	2.203	5.968
1996	27.127	22.576	17.722	15.282	10.550	5.321	3.046	5.694
1997	25.044	22.655	17.565	12.977	10.720	7.321	3.525	5.788
1998	28.456	20.848	17.207	12.488	8.779	7.082	4.574	5.822
1999	31.814	23.662	15.553	11.997	8.246	5.665	4.224	6.203
2000	41.315	26.926	18.954	11.993	9.022	6.105	4.074	7.501
2001	37.138	34.394	19.972	12.876	7.695	5.563	3.526	6.690
2002	32.249	30.733	24.541	12.571	7.476	4.236	2.747	5.047
2003	25.047	26.769	22.081	15.489	7.337	4.075	2.172	4.003
2004	19.789	20.840	19.338	13.959	8.899	3.900	2.017	3.048
2005	17.676	16.553	15.376	12.658	8.330	4.981	2.054	2.668
2006	17.186	14.865	12.588	10.563	7.965	4.949	2.841	2.693
2007	16.567	14.552	11.789	9.284	7.297	5.195	3.128	3.495
2008	16.870	14.016	11.554	8.686	6.434	4.674	3.239	4.120
2009	20.678	14.254	11.061	8.413	5.891	3.981	2.770	4.336
2010	25.509	17.552	11.474	8.241	5.893	3.816	2.488	4.425
2011	25.607	21.719	14.325	8.713	5.935	3.998	2.484	4.506
2012	27.040	21.841	17.810	10.917	6.283	4.063	2.606	4.565
2013	23.590	23.014	17.837	13.194	7.465	4.078	2.488	4.396
2014	22.692	20.080	18.803	13.236	8.879	4.722	2.417	4.082
2015	31.928	19.325	16.456	13.974	8.879	5.492	2.814	3.884
2016	32.538	27.187	15.889	12.334	9.494	5.526	3.228	3.943

Table 3.6.8: North West. Standard errors of estimates of population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	1.671	1.527	1.749	1.581	1.368	1.122	0.781	1.998
1983	1.627	1.371	1.208	1.360	1.220	1.032	0.824	1.521
1984	1.520	1.342	1.098	0.966	1.082	0.959	0.794	1.460
1985	1.502	1.256	1.096	0.882	0.764	0.844	0.743	1.540
1986	1.358	1.244	1.024	0.887	0.706	0.610	0.668	1.643
1987	1.179	1.123	1.009	0.831	0.713	0.565	0.485	1.657
1988	0.899	0.967	0.902	0.807	0.659	0.566	0.434	1.514
1989	0.825	0.741	0.784	0.724	0.641	0.529	0.434	1.380
1990	0.985	0.683	0.604	0.629	0.579	0.510	0.407	1.273
1991	1.024	0.811	0.557	0.485	0.501	0.456	0.394	1.181
1992	1.306	0.836	0.650	0.437	0.372	0.381	0.345	1.058
1993	1.211	1.065	0.665	0.501	0.329	0.281	0.288	0.929
1994	1.066	0.988	0.847	0.511	0.377	0.249	0.213	0.807
1995	1.117	0.864	0.775	0.613	0.365	0.278	0.186	0.679
1996	1.098	0.930	0.704	0.605	0.481	0.290	0.225	0.631
1997	1.068	0.913	0.736	0.523	0.456	0.370	0.224	0.582
1998	1.289	0.879	0.713	0.533	0.380	0.341	0.279	0.538
1999	1.451	1.062	0.670	0.509	0.376	0.279	0.256	0.542
2000	1.750	1.221	0.854	0.518	0.392	0.292	0.220	0.579
2001	1.716	1.440	0.922	0.601	0.356	0.277	0.209	0.516
2002	1.522	1.388	1.041	0.592	0.374	0.220	0.173	0.416
2003	1.302	1.244	0.996	0.693	0.382	0.237	0.143	0.363
2004	1.074	1.065	0.908	0.636	0.442	0.232	0.143	0.286
2005	0.960	0.886	0.789	0.600	0.415	0.284	0.150	0.262
2006	0.855	0.799	0.669	0.543	0.412	0.288	0.205	0.284
2007	0.780	0.722	0.644	0.514	0.407	0.308	0.219	0.341
2008	0.750	0.658	0.576	0.488	0.386	0.303	0.230	0.387
2009	0.900	0.632	0.510	0.406	0.330	0.261	0.219	0.440
2010	1.206	0.761	0.516	0.395	0.310	0.243	0.200	0.470
2011	1.420	1.025	0.628	0.401	0.301	0.230	0.184	0.468
2012	1.729	1.208	0.851	0.506	0.317	0.235	0.182	0.460
2013	1.984	1.475	1.012	0.688	0.401	0.246	0.185	0.448
2014	2.361	1.698	1.248	0.823	0.552	0.321	0.200	0.451
2015	3.121	2.020	1.431	1.021	0.656	0.437	0.258	0.475
2016	5.792	2.673	1.716	1.189	0.849	0.537	0.350	0.547

Table 3.6.9: North West. Estimates of fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	0.051	0.105	0.130	0.167	0.201	0.250	0.250	0.250
1983	0.044	0.090	0.110	0.150	0.179	0.231	0.231	0.231
1984	0.046	0.098	0.117	0.158	0.182	0.228	0.228	0.228
1985	0.037	0.081	0.098	0.129	0.147	0.188	0.188	0.188
1986	0.038	0.084	0.105	0.141	0.154	0.215	0.215	0.215
1987	0.045	0.103	0.134	0.180	0.191	0.288	0.288	0.288
1988	0.042	0.099	0.136	0.175	0.194	0.277	0.277	0.277
1989	0.048	0.117	0.167	0.215	0.250	0.309	0.309	0.309
1990	0.038	0.097	0.137	0.180	0.204	0.243	0.243	0.243
1991	0.037	0.103	0.148	0.199	0.209	0.230	0.230	0.230
1992	0.034	0.096	0.149	0.194	0.200	0.223	0.223	0.223
1993	0.026	0.078	0.126	0.163	0.163	0.183	0.183	0.183
1994	0.029	0.090	0.154	0.191	0.191	0.215	0.215	0.215
1995	0.026	0.084	0.138	0.179	0.182	0.212	0.212	0.212
1996	0.029	0.101	0.161	0.205	0.215	0.262	0.262	0.262
1997	0.034	0.125	0.191	0.241	0.265	0.321	0.321	0.321
1998	0.036	0.143	0.211	0.265	0.289	0.367	0.367	0.367
1999	0.017	0.072	0.109	0.134	0.150	0.180	0.180	0.180
2000	0.034	0.149	0.236	0.294	0.334	0.400	0.400	0.400
2001	0.041	0.187	0.313	0.394	0.445	0.556	0.556	0.556
2002	0.038	0.181	0.310	0.389	0.457	0.519	0.519	0.519
2003	0.037	0.175	0.308	0.404	0.483	0.555	0.555	0.555
2004	0.032	0.154	0.273	0.366	0.430	0.494	0.494	0.494
2005	0.025	0.125	0.226	0.313	0.370	0.410	0.410	0.410
2006	0.017	0.082	0.155	0.220	0.277	0.308	0.308	0.308
2007	0.016	0.079	0.155	0.217	0.296	0.324	0.324	0.324
2008	0.017	0.080	0.165	0.237	0.328	0.373	0.373	0.373
2009	0.014	0.065	0.142	0.206	0.285	0.321	0.321	0.321
2010	0.011	0.053	0.122	0.175	0.235	0.280	0.280	0.280
2011	0.010	0.048	0.121	0.176	0.228	0.279	0.279	0.279
2012	0.011	0.053	0.151	0.231	0.282	0.342	0.342	0.342
2013	0.011	0.052	0.149	0.247	0.310	0.375	0.375	0.375
2014	0.011	0.050	0.147	0.250	0.331	0.370	0.370	0.370
2015	0.011	0.046	0.139	0.238	0.326	0.384	0.384	0.384

Table 3.6.10: 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	0.006	0.010	0.013	0.016	0.020	0.024	0.024	0.024
1983	0.006	0.010	0.012	0.016	0.020	0.025	0.025	0.025
1984	0.007	0.011	0.013	0.017	0.021	0.025	0.025	0.025
1985	0.005	0.009	0.011	0.014	0.017	0.021	0.021	0.021
1986	0.006	0.010	0.012	0.015	0.017	0.023	0.023	0.023
1987	0.007	0.012	0.015	0.019	0.021	0.030	0.030	0.030
1988	0.007	0.011	0.016	0.019	0.022	0.029	0.029	0.029
1989	0.008	0.013	0.019	0.023	0.028	0.032	0.032	0.032
1990	0.006	0.011	0.016	0.019	0.022	0.025	0.025	0.025
1991	0.006	0.012	0.017	0.022	0.023	0.024	0.024	0.024
1992	0.005	0.011	0.017	0.021	0.023	0.025	0.025	0.025
1993	0.004	0.009	0.015	0.018	0.019	0.022	0.022	0.022
1994	0.005	0.011	0.018	0.021	0.021	0.026	0.026	0.026
1995	0.004	0.010	0.015	0.019	0.019	0.023	0.023	0.023
1996	0.005	0.011	0.017	0.020	0.022	0.025	0.025	0.025
1997	0.005	0.013	0.020	0.023	0.026	0.030	0.030	0.030
1998	0.006	0.015	0.022	0.025	0.028	0.034	0.034	0.034
1999	0.003	0.010	0.015	0.017	0.019	0.022	0.022	0.022
2000	0.005	0.016	0.025	0.028	0.032	0.036	0.036	0.036
2001	0.007	0.019	0.031	0.035	0.040	0.046	0.046	0.046
2002	0.006	0.019	0.031	0.036	0.042	0.046	0.046	0.046
2003	0.006	0.018	0.031	0.037	0.044	0.049	0.049	0.049
2004	0.005	0.016	0.028	0.034	0.041	0.046	0.046	0.046
2005	0.004	0.014	0.024	0.030	0.036	0.040	0.040	0.040
2006	0.003	0.009	0.017	0.022	0.029	0.030	0.030	0.030
2007	0.003	0.009	0.018	0.023	0.031	0.031	0.031	0.031
2008	0.003	0.013	0.027	0.038	0.052	0.060	0.060	0.060
2009	0.002	0.008	0.016	0.022	0.030	0.033	0.033	0.033
2010	0.002	0.006	0.014	0.018	0.025	0.028	0.028	0.028
2011	0.002	0.006	0.014	0.018	0.024	0.029	0.029	0.029
2012	0.002	0.006	0.017	0.024	0.030	0.035	0.035	0.035
2013	0.002	0.006	0.018	0.026	0.034	0.040	0.040	0.040
2014	0.002	0.007	0.019	0.029	0.038	0.042	0.042	0.042
2015	0.002	0.007	0.021	0.032	0.043	0.048	0.048	0.048

Table 3.6.11: North West. Stock summary from the final TSA run. Catch estimate and Mean F in 2016 are model forecasts.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1982	3294	3144	22149	22737	0.134
1983	2335	2350	18173	20559	0.117
1984	2556	2492	18789	18576	0.125
1985	1812	1874	16670	16277	0.103
1986	1723	1789	14464	14993	0.110
1987	2091	1929	12365	13538	0.139
1988	1849	1724	11361	10417	0.137
1989	1750	1731	10129	12333	0.166
1990	1424	1296	10118	17261	0.138
1991	1273	1292	10606	20918	0.150
1992	1258	1344	12785	30236	0.146
1993	1122	1351	15329	31128	0.122
1994	2009	1867	16819	26761	0.145
1995	1817	1858	17405	26921	0.134
1996	2324	2265	17605	27127	0.156
1997	2773	2778	17688	25044	0.186
1998	3072	2953	17609	28456	0.206
1999	1254	1631	18352	31814	0.105
2000	3478	3558	21184	41315	0.226
2001	4376	4324	20338	37138	0.298
2002	4532	4135	19606	32249	0.293
2003	3756	3808	17091	25047	0.296
2004	3296	3178	14950	19789	0.264
2005	2655	2556	13499	17676	0.221
2006	1357	1656	11849	17186	0.152
2007	1532	1576	10995	16567	0.150
2008	2406	2073	12709	16870	0.161
2009	1547	1586	12138	20678	0.138
2010	1365	1424	13361	25509	0.117
2011	1391	1421	14610	25607	0.115
2012	1785	1793	14585	27040	0.145
2013	2054	2056	15394	23590	0.149
2014	2261	2231	15662	22692	0.149
2015	2236	2127	16278	31928	0.141
2016	NA	2306	17581	32538	0.148

Table 3.8.1: 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	793	1167	1098	927	629	318	338
2011	0	31	391	575	927	919	764	475	534
2012	0	155	485	781	856	977	1232	792	553
2013	0	41	744	1063	994	1109	1271	986	1066
2014	0	22	200	944	971	892	846	650	679
2015	0	59	305	693	1354	1041	762	645	860

Table 3.8.2: Shetland. Mean weights-at-age (total live weight) (kg) in total catch (also used for stock weights).

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**
1986	0.114	0.139	0.145	0.152	0.160	0.166	0.188	0.235	0.223
1987	0.128	0.140	0.160	0.177	0.191	0.199	0.210	0.222	0.259
1988	0.132	0.143	0.163	0.179	0.193	0.204	0.209	0.217	0.244
1989	0.118	0.136	0.149	0.163	0.177	0.190	0.204	0.217	0.242
1990	0.120	0.134	0.149	0.162	0.173	0.189	0.203	0.218	0.226
1991	0.107	0.133	0.147	0.166	0.174	0.188	0.198	0.207	0.221
1992	0.111	0.129	0.149	0.161	0.180	0.194	0.202	0.209	0.223
1993	0.091	0.126	0.139	0.154	0.177	0.191	0.201	0.211	0.235
1994	0.103	0.123	0.137	0.151	0.176	0.199	0.203	0.215	0.232
1995	0.101	0.119	0.139	0.159	0.163	0.194	0.213	0.215	0.229
1996	0.091	0.117	0.130	0.145	0.167	0.191	0.212	0.214	0.234
1997	0.091	0.127	0.134	0.149	0.165	0.182	0.197	0.212	0.228
1998	0.129	0.125	0.138	0.146	0.162	0.174	0.186	0.199	0.215
1999	0.129	0.127	0.140	0.150	0.167	0.183	0.198	0.212	0.234
2000	0.132	0.140	0.145	0.154	0.164	0.180	0.197	0.216	0.229
2001	0.130	0.126	0.138	0.158	0.170	0.187	0.193	0.203	0.229
2002	0.130	0.126	0.140	0.153	0.169	0.186	0.196	0.202	0.221
2003	0.132	0.130	0.144	0.167	0.182	0.195	0.203	0.212	0.243
2004	0.146	0.132	0.147	0.168	0.189	0.203	0.211	0.222	0.251
2005	0.120	0.139	0.154	0.166	0.184	0.200	0.211	0.232	0.256
2006	0.122	0.136	0.157	0.169	0.182	0.195	0.211	0.218	0.239
2007	0.129	0.130	0.149	0.175	0.190	0.207	0.222	0.242	0.261
2008	0.121	0.142	0.151	0.167	0.187	0.202	0.215	0.229	0.248
2009	0.122	0.146	0.164	0.184	0.197	0.214	0.232	0.242	0.255
2010	0.122	0.146	0.159	0.178	0.196	0.214	0.227	0.237	0.251
2011	0.122	0.132	0.149	0.165	0.181	0.199	0.215	0.229	0.244
2012	0.122	0.139	0.155	0.168	0.179	0.196	0.214	0.226	0.246
2013	0.122	0.131	0.143	0.162	0.179	0.197	0.209	0.219	0.239
2014	0.122	0.135	0.153	0.164	0.175	0.192	0.209	0.226	0.247
2015	0.122	0.137	0.147	0.168	0.176	0.192	0.203	0.216	0.230

Table 3.8.3: Summary of Marine Scotland Science Shetland scallop dredge surveys. Due to poor weather conditions, no survey data are available from 2014 or 2015 and in 2016 only a partial survey was completed. 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					
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	48	6221
R.V. Alba na Mara	15-Mar-10	29-Mar-10	A B	6 6	9	85	12847
R.V. Alba na Mara	31-Jan-11	14-Feb-11	A B	6 6	9	65	10612
R.V. Alba na Mara	23-Jan-12	06-Feb-12	A B	6 6	9	64	6200
R.V. Alba na Mara	08-Jan-13	19-Jan-13	A B	6 6	9	64	6706
R.V. Alba na Mara	26-Jan-16	08-Feb-16	A B	6 6	9	19	2260

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 3.8.4: Shetland. Research-vessel survey data. Catch rates (numbers $hour^{-1} metre^{-1}$) by age class and year.

Clupea

	2	3	4	5	6	7	8	9	10+
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

Alba

	2	3	4	5	6	7	8	9	10+
2009	0.050	1.100	2.340	4.940	4.580	3.560	2.700	0.950	6.920
2010	0.020	1.830	3.510	5.440	5.340	4.050	2.420	0.860	8.120
2011	0.040	1.140	3.540	5.180	4.480	5.140	3.930	1.750	8.920
2012	0.000	0.850	2.610	4.220	3.040	3.350	2.340	1.330	4.170
2013	0.000	0.710	3.850	3.610	3.370	3.340	2.760	1.710	4.390
2014	NA	NA	NA	NA	NA	NA	NA	NA	NA
2015	NA	NA	NA	NA	NA	NA	NA	NA	NA
2016	0	0.28	2.39	2.47	3.29	3.67	2.93	1.66	9.3

Table 3.8.5: Shetland. TSA final assessment input settings.

Quantity	Setting	Notes
Landings	Ages 3 – 10+ Years 1984-2015	
Survey:Clupea	Ages 3-9 Years 1998-2008	
Survey:Alba	Ages 3-9 Years 2009-2016	Excluding 2014 & 2015 when poor weather prevented the survey taking place
Maturity	100 % for age 3 onwards	
Natural mortality	Fixed at 0.15 for all ages	
Stock weights	Equal to catch weights	
F plateau	Age 9	
Recruitment	Modelled as random walk	
Annual survey CV multiplier	Adjusted according to the number of survey hauls	Allows for greater variability when fewer hauls
Survey age CV multiplier: Clupea	(2.5,1.5,1,1,1,1,1.2)	Allows for greater variability at younger & older ages
Survey age CV multiplier: Alba	(2.2,1,1,1,1,1.2,1.4)	Allows for greater variability at younger & older ages
Recruitment variability	1992: CV multiplier = 3.0	Allows greater variability to capture big increase in these years
Catch CV multiplier	(2.5,1.5,1,1,1,1,1,1)	Allows for greater variability at ages 3,4 & 10+
Multipliers on variances for fishing mortality estimates.	H(3) = 3; H(4) = 2	Allows for more variable fishing mortalities for ages 3 & 4

Table 3.8.6: Shetland. Final TSA run parameter estimates.

Parameter	Notation	Description	2016
Initial fishing mortality	F(3, 1984)	Fishing mortality at age a in year y	0.026
	F(4, 1984)		0.050
	F(8, 1984)		0.214
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0.196
	σ_U	Persistent changes in selection (age effect in F)	0.099
	σ_V	Transitory changes in the year effect in F	0.185
	σ_Y	Persistent changes in the year effect in F	0.143
Measurement cv	cv_{catch}	Coefficient of variation of catch-at-age data	0.110
Recruitment		Log mean recruitment at start	1.403
	s_{rw}	Standard deviation of random walk	0.228
	cv_{rec}	Coefficient of variation of recruitment curve	0.125
Survey selectivities: Clupea	$\Phi_c(3)$	Survey selectivity at age a	0.197
	Φ_c (4)		0.756
	Φ_c (5)		0.868
	Φ_c (6)		1.192
	Φ_c (7)		1.873
	Φ_c (8)		2.441
	Φ_c (9)		2.906
Survey catchability standard deviations: Clupea	$\sigma_{c\Omega}$	Transitory changes in survey catchability	0.110
	$\sigma_{c\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Clupea	$\sigma_{csurvey}$	Coefficient of variation controlling gamma type dispersion	0.278
	$\eta_{csurvey}$	Coefficient of variation controlling poisson type dispersion	0.252
Survey selectivities: Alba	$\Phi_a(3)$	Survey selectivity at age a	0.126
	Φ_a (4)		0.359
	Φ_a (5)		0.628
	Φ_a (6)		0.702
	Φ_a (7)		0.878
	Φ_a (8)		1.043
	Φ_a (9)		0.850
Survey catchability standard deviations: Alba	$\sigma_{a\Omega}$	Transitory changes in survey catchability	0.181
	$\sigma_{a\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Alba	$\sigma_{asurvey}$	Coefficient of variation controlling gamma type dispersion	0.009
	$\eta_{asurvey}$	Coefficient of variation controlling poisson type dispersion	0.281

[1] Fixed parameter.

Table 3.8.7: Shetland. Estimated population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10
1986	4.582	4.044	3.772	3.285	2.575	1.596	1.409	1.752
1987	3.965	3.888	3.382	3.003	2.446	1.896	1.160	2.226
1988	2.782	3.355	3.155	2.698	2.394	1.885	1.440	2.500
1989	2.635	2.311	2.638	2.446	2.073	1.876	1.448	2.916
1990	3.391	2.195	1.763	1.968	1.764	1.302	1.194	2.969
1991	6.165	2.787	1.755	1.309	1.411	1.268	0.902	2.897
1992	13.248	5.213	2.237	1.311	0.911	0.979	0.830	2.579
1993	12.077	10.843	4.022	1.560	0.888	0.636	0.662	2.209
1994	11.610	10.844	8.337	2.470	1.092	0.641	0.441	1.924
1995	10.119	9.857	8.639	5.717	1.733	0.779	0.450	1.620
1996	7.461	8.591	7.815	6.048	3.857	1.239	0.549	1.407
1997	4.379	6.162	6.902	5.597	4.140	2.664	0.856	1.301
1998	3.632	3.702	4.675	4.749	3.774	2.725	1.768	1.415
1999	5.345	2.856	2.919	3.296	3.063	2.169	1.452	1.568
2000	8.388	4.535	2.275	2.107	1.999	1.781	1.244	1.779
2001	7.816	7.166	3.729	1.781	1.556	1.404	1.194	2.131
2002	8.746	6.683	5.397	2.723	1.296	1.090	0.905	2.248
2003	8.137	7.477	5.464	3.602	1.755	0.833	0.672	2.084
2004	8.071	6.939	5.917	3.803	2.189	1.073	0.461	1.638
2005	11.421	6.815	5.231	3.838	2.332	1.263	0.648	1.336
2006	13.489	9.235	5.408	3.854	2.596	1.527	0.802	1.348
2007	12.975	11.397	7.263	4.021	2.725	1.727	0.962	1.230
2008	12.031	11.066	8.982	5.215	2.844	1.859	1.118	1.440
2009	10.890	10.258	8.948	6.649	3.739	1.884	1.137	1.502
2010	10.515	9.273	8.375	7.044	4.867	2.644	1.192	1.480
2011	10.419	8.967	7.403	6.333	5.194	3.395	1.716	1.689
2012	12.259	8.912	7.348	5.797	4.677	3.690	2.244	2.033
2013	7.777	10.448	7.298	5.657	4.255	3.196	2.101	2.456
2014	5.898	6.642	8.347	5.294	3.942	2.629	1.595	1.916
2015	6.772	5.039	5.470	6.340	3.704	2.590	1.518	1.841
2016	6.137	5.779	4.088	4.102	4.262	2.262	1.525	1.541

Table 3.8.8: Shetland. Standard errors of estimates of population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10
1986	0.368	0.247	0.312	0.399	0.341	0.220	0.206	0.240
1987	0.348	0.314	0.209	0.264	0.334	0.285	0.183	0.251
1988	0.267	0.298	0.266	0.186	0.221	0.278	0.236	0.262
1989	0.228	0.226	0.249	0.225	0.154	0.181	0.225	0.285
1990	0.272	0.189	0.180	0.204	0.185	0.127	0.149	0.290
1991	0.404	0.222	0.154	0.149	0.170	0.152	0.106	0.282
1992	0.737	0.341	0.182	0.125	0.122	0.140	0.126	0.258
1993	2.209	0.651	0.280	0.149	0.099	0.098	0.114	0.241
1994	0.643	0.618	0.493	0.201	0.109	0.071	0.070	0.205
1995	0.547	0.540	0.473	0.370	0.157	0.086	0.055	0.184
1996	0.460	0.462	0.427	0.364	0.292	0.128	0.070	0.170
1997	0.262	0.366	0.376	0.324	0.288	0.238	0.107	0.174
1998	0.566	0.222	0.277	0.295	0.258	0.235	0.199	0.203
1999	0.292	0.154	0.170	0.195	0.219	0.183	0.172	0.218
2000	0.409	0.249	0.121	0.133	0.153	0.174	0.148	0.238
2001	0.407	0.352	0.211	0.104	0.112	0.130	0.148	0.255
2002	0.450	0.350	0.273	0.173	0.084	0.091	0.105	0.255
2003	0.412	0.386	0.292	0.207	0.131	0.070	0.075	0.237
2004	0.407	0.352	0.307	0.227	0.155	0.100	0.057	0.213
2005	0.583	0.346	0.256	0.226	0.164	0.114	0.077	0.185
2006	0.629	0.466	0.278	0.206	0.175	0.128	0.090	0.170
2007	0.517	0.527	0.362	0.219	0.161	0.137	0.104	0.177
2008	0.486	0.440	0.401	0.277	0.170	0.126	0.110	0.183
2009	0.573	0.414	0.349	0.314	0.219	0.131	0.100	0.185
2010	0.699	0.489	0.340	0.298	0.256	0.181	0.115	0.192
2011	0.809	0.601	0.412	0.301	0.253	0.207	0.145	0.200
2012	1.107	0.693	0.506	0.349	0.253	0.216	0.178	0.238
2013	1.292	0.949	0.587	0.427	0.290	0.209	0.169	0.261
2014	1.516	1.109	0.818	0.492	0.360	0.246	0.169	0.264
2015	1.736	1.300	0.939	0.698	0.421	0.309	0.211	0.310
2016	2.241	1.489	1.096	0.792	0.605	0.366	0.270	0.428

Table 3.8.9: Shetland. Estimates of fishing mortality by age and year from the final TSA run.

	3	4	5	6	7	8	9	10
1986	0.015	0.022	0.078	0.127	0.151	0.173	0.208	0.206
1987	0.018	0.060	0.076	0.078	0.104	0.126	0.143	0.165
1988	0.032	0.090	0.106	0.113	0.094	0.119	0.131	0.166
1989	0.034	0.112	0.144	0.178	0.319	0.309	0.230	0.243
1990	0.052	0.084	0.144	0.187	0.187	0.225	0.222	0.230
1991	0.019	0.078	0.153	0.205	0.221	0.286	0.259	0.257
1992	0.051	0.114	0.204	0.237	0.209	0.250	0.247	0.314
1993	0.019	0.115	0.357	0.232	0.206	0.255	0.274	0.273
1994	0.016	0.082	0.235	0.217	0.204	0.214	0.249	0.249
1995	0.014	0.083	0.209	0.251	0.193	0.210	0.271	0.240
1996	0.014	0.052	0.164	0.221	0.217	0.216	0.252	0.254
1997	0.018	0.126	0.227	0.244	0.269	0.260	0.269	0.282
1998	0.019	0.088	0.194	0.291	0.408	0.483	0.492	0.683
1999	0.014	0.076	0.179	0.357	0.398	0.416	0.388	0.414
2000	0.007	0.046	0.094	0.155	0.204	0.247	0.207	0.200
2001	0.007	0.134	0.164	0.167	0.208	0.292	0.208	0.265
2002	0.007	0.052	0.256	0.290	0.294	0.338	0.286	0.258
2003	0.010	0.085	0.214	0.349	0.344	0.448	0.335	0.379
2004	0.020	0.135	0.288	0.343	0.405	0.362	0.376	0.291
2005	0.062	0.082	0.156	0.244	0.277	0.309	0.293	0.222
2006	0.019	0.091	0.147	0.196	0.260	0.316	0.299	0.488
2007	0.009	0.086	0.183	0.194	0.226	0.286	0.270	0.277
2008	0.008	0.050	0.147	0.183	0.253	0.332	0.408	0.378
2009	0.010	0.042	0.082	0.160	0.198	0.311	0.506	0.393
2010	0.010	0.076	0.129	0.152	0.207	0.281	0.329	0.306
2011	0.006	0.049	0.095	0.152	0.192	0.266	0.350	0.404
2012	0.010	0.050	0.112	0.159	0.229	0.408	0.457	0.358
2013	0.008	0.076	0.171	0.213	0.333	0.544	0.779	0.684
2014	0.008	0.046	0.127	0.209	0.274	0.406	0.540	0.480
2015	0.009	0.064	0.143	0.252	0.351	0.389	0.616	0.715
2016	0.013	0.071	0.145	0.230	0.319	0.424	0.611	0.613

Table 3.8.10: 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	10
1986	0.005	0.005	0.010	0.016	0.020	0.026	0.035	0.033
1987	0.006	0.013	0.012	0.010	0.014	0.018	0.024	0.025
1988	0.012	0.019	0.014	0.015	0.013	0.017	0.021	0.025
1989	0.013	0.023	0.018	0.023	0.041	0.046	0.040	0.037
1990	0.019	0.018	0.018	0.025	0.026	0.033	0.037	0.035
1991	0.007	0.017	0.020	0.026	0.030	0.041	0.040	0.038
1992	0.017	0.024	0.026	0.029	0.027	0.036	0.039	0.045
1993	0.007	0.023	0.041	0.029	0.027	0.037	0.045	0.039
1994	0.006	0.018	0.028	0.028	0.030	0.038	0.053	0.043
1995	0.005	0.018	0.027	0.031	0.028	0.035	0.057	0.045
1996	0.005	0.012	0.022	0.028	0.028	0.034	0.049	0.051
1997	0.007	0.028	0.031	0.031	0.034	0.036	0.048	0.055
1998	0.007	0.019	0.025	0.035	0.048	0.059	0.069	0.114
1999	0.006	0.016	0.022	0.041	0.048	0.054	0.059	0.073
2000	0.003	0.010	0.013	0.020	0.027	0.035	0.033	0.035
2001	0.003	0.026	0.020	0.021	0.027	0.039	0.030	0.040
2002	0.003	0.011	0.029	0.033	0.037	0.046	0.042	0.037
2003	0.004	0.018	0.025	0.039	0.041	0.060	0.050	0.052
2004	0.007	0.026	0.031	0.038	0.046	0.048	0.059	0.042
2005	0.022	0.017	0.019	0.029	0.034	0.042	0.047	0.036
2006	0.007	0.019	0.018	0.023	0.032	0.043	0.047	0.081
2007	0.003	0.017	0.021	0.023	0.028	0.039	0.041	0.045
2008	0.003	0.010	0.017	0.022	0.031	0.044	0.063	0.058
2009	0.004	0.009	0.011	0.019	0.025	0.044	0.082	0.063
2010	0.004	0.016	0.016	0.018	0.025	0.037	0.051	0.053
2011	0.003	0.011	0.012	0.019	0.024	0.035	0.053	0.070
2012	0.004	0.011	0.015	0.021	0.028	0.049	0.065	0.057
2013	0.003	0.018	0.025	0.029	0.045	0.070	0.118	0.113
2014	0.003	0.012	0.020	0.033	0.043	0.067	0.105	0.109
2015	0.004	0.018	0.031	0.044	0.065	0.076	0.147	0.211
2016	0.009	0.036	0.055	0.086	0.119	0.161	0.238	0.239

Table 3.8.11: Shetland. Stock summary from the final TSA run.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1986	368	341	3773	4582	0.076
1987	311	323	4067	3965	0.072
1988	360	361	3835	2782	0.103
1989	535	556	3362	2635	0.144
1990	446	412	2937	3391	0.139
1991	425	399	3090	6165	0.146
1992	521	513	4203	13248	0.185
1993	577	604	4873	12077	0.235
1994	634	621	5495	11610	0.178
1995	764	726	5852	10119	0.181
1996	675	681	5580	7461	0.146
1997	932	861	5089	4379	0.199
1998	926	990	4231	3632	0.191
1999	755	768	3734	5345	0.204
2000	336	357	3909	8388	0.099
2001	496	509	4158	7816	0.155
2002	572	592	4457	8746	0.199
2003	763	768	4862	8137	0.216
2004	895	892	4982	8071	0.256
2005	720	692	5429	11421	0.161
2006	775	726	6227	13489	0.145
2007	861	783	6925	12975	0.154
2008	880	837	7442	12031	0.126
2009	915	835	8120	10890	0.095
2010	1072	942	8181	10515	0.119
2011	911	878	7651	10419	0.099
2012	1151	1071	8070	12259	0.107
2013	1418	1440	7266	7777	0.153
2014	1024	999	6249	5898	0.127
2015	1099	1063	5689	6772	0.153
2016	NA	919	5074	6137	0.149

Table 3.9.1: 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	673	1822	1490	1726	1128	641	294	512
2010	0	1130	2216	2067	1285	740	497	245	567
2011	0	13	920	1960	1689	1217	998	460	845
2012	0	62	1125	2858	3705	2997	1576	884	960
2013	0	88	959	1719	1901	1733	1108	545	856
2014	5	604	1565	2182	2735	2444	1694	995	849
2015	2	292	808	1666	1809	1524	986	603	419

Table 3.9.2: West of Kintyre. Mean weights-at-age (total live weight) (kg) in total catch (also used for stock weights).

	2	3	4	5	6	7	8	9	10+
1982	0.115	0.127	0.138	0.163	0.189	0.198	0.214	0.222	0.249
1983	0.092	0.121	0.141	0.148	0.155	0.165	0.182	0.203	0.238
1984	0.097	0.124	0.160	0.185	0.198	0.206	0.212	0.225	0.248
1985	0.112	0.131	0.161	0.183	0.192	0.197	0.207	0.213	0.230
1986	0.105	0.119	0.143	0.170	0.189	0.200	0.199	0.209	0.228
1987	0.100	0.127	0.151	0.175	0.193	0.207	0.217	0.223	0.240
1988	0.107	0.124	0.136	0.163	0.177	0.191	0.205	0.210	0.231
1989	0.116	0.136	0.151	0.170	0.186	0.206	0.203	0.212	0.239
1990	0.101	0.132	0.161	0.183	0.200	0.209	0.214	0.228	0.260
1991	0.111	0.139	0.165	0.184	0.198	0.208	0.222	0.227	0.255
1992	0.120	0.128	0.137	0.165	0.188	0.203	0.214	0.221	0.242
1993	0.110	0.125	0.154	0.180	0.201	0.220	0.229	0.229	0.246
1994	0.127	0.137	0.147	0.162	0.183	0.214	0.231	0.234	0.270
1995	0.136	0.140	0.160	0.183	0.201	0.218	0.232	0.244	0.244
1996	0.113	0.132	0.151	0.171	0.193	0.210	0.227	0.234	0.247
1997	0.122	0.138	0.159	0.180	0.198	0.212	0.222	0.233	0.220
1998	0.097	0.132	0.152	0.170	0.186	0.205	0.217	0.228	0.237
1999	0.126	0.143	0.151	0.174	0.195	0.210	0.220	0.228	0.236
2000	0.115	0.134	0.157	0.169	0.187	0.199	0.213	0.228	0.248
2001	0.111	0.128	0.152	0.172	0.191	0.207	0.213	0.216	0.232
2002	0.137	0.146	0.148	0.164	0.187	0.201	0.210	0.214	0.236
2003	0.123	0.138	0.145	0.160	0.187	0.203	0.219	0.227	0.248
2004	0.123	0.147	0.151	0.165	0.187	0.207	0.226	0.233	0.244
2005	0.146	0.142	0.162	0.177	0.191	0.214	0.244	0.253	0.280
2006	0.131	0.118	0.141	0.161	0.197	0.220	0.244	0.276	0.274
2007	0.146	0.136	0.158	0.182	0.196	0.199	0.221	0.258	0.263
2008	0.114	0.128	0.152	0.171	0.193	0.211	0.234	0.266	0.291
2009	0.134	0.131	0.141	0.152	0.165	0.187	0.202	0.214	0.247
2010	0.134	0.138	0.149	0.158	0.177	0.194	0.204	0.219	0.245
2011	0.134	0.130	0.137	0.150	0.165	0.181	0.194	0.197	0.210
2012	0.134	0.128	0.132	0.146	0.162	0.180	0.193	0.205	0.236
2013	0.134	0.131	0.145	0.162	0.180	0.200	0.218	0.241	0.262
2014	0.114	0.133	0.141	0.156	0.175	0.193	0.209	0.228	0.256
2015	0.100	0.120	0.137	0.152	0.168	0.183	0.200	0.217	0.241

Table 3.9.3: West of Kintyre. Research-vessel survey data. Catch rates (numbers hour^{-1}metre^{-1}) by age and year.

Aora

	2	3	4	5	6	7	8	9	10+
1993	0.822	10.654	10.012	5.947	4.408	1.853	1.240	1.121	3.482
1994	0.130	4.297	13.524	9.841	4.725	3.702	1.228	0.781	2.214
1995	0.402	10.123	11.616	8.879	4.344	2.143	1.186	0.536	1.703
1996	0.124	4.136	9.105	7.153	5.485	2.787	1.367	0.958	2.112
1997	0.243	5.693	12.584	9.588	5.805	3.708	1.779	0.918	1.704
1998	0.206	7.880	11.707	9.981	5.947	4.371	2.139	1.201	1.651
1999	0.054	4.587	6.804	7.135	5.374	4.265	3.263	1.824	1.958
2000	0.048	6.632	13.231	8.581	5.817	4.155	2.828	1.486	1.454
2001	0.797	2.188	10.229	8.278	4.241	2.646	2.019	1.221	1.883
2002	0.017	9.905	5.126	10.234	7.602	3.446	2.424	1.229	4.312

Aora II

	2	3	4	5	6	7	8	9	10+
2003	0.417	5.605	13.007	4.898	6.122	3.057	1.932	1.605	2.249
2004	1.181	5.279	6.348	9.705	3.563	3.844	2.119	1.622	2.438
2005	0.153	9.745	10.004	6.772	6.167	3.338	2.273	1.477	2.129
2006	0.040	4.387	9.803	12.547	8.684	4.902	3.833	2.380	2.350
2007	0.022	2.186	8.018	8.446	7.754	4.986	3.471	2.724	3.723

Alba

	2	3	4	5	6	7	8	9	10+
2008	0.066	2.122	5.667	7.072	5.686	3.923	2.018	1.452	2.056
2009	0.070	4.600	14.070	8.960	5.000	3.300	2.320	0.740	4.620
2010	0.030	9.710	14.230	8.260	3.730	2.170	0.980	0.250	4.020
2011	0.010	1.460	8.520	13.540	7.420	5.040	2.050	1.440	4.310
2012	0.000	3.420	10.000	11.220	6.750	4.070	2.390	1.350	2.970
2013	0.030	3.810	11.310	10.080	6.270	4.070	2.060	1.210	2.630
2014	0.040	2.110	8.600	11.190	7.350	4.640	2.810	1.250	3.170
2015	0.14	3.26	9.77	9.42	9.82	7.65	3.79	1.77	4.51
2016	0.01	1.94	15.6	8.14	5.88	5.45	3.16	1.77	5.79

Table 3.9.4: West of Kintyre. T SA final assessment input settings.

Quantity	Setting	Notes
Landings	Ages 3 – 10+ Years 1982--2015	
Survey:Aora	Ages 3-9 Years 1993-2002	1993 & 1994 Aora survey indices omitted – have much higher catchability than the rest of the time series.
Survey: Aora II	Ages 3-9 Years 2003-2007	
Survey:Alba	Ages 3-9 Years 2008-2016	
Maturity	100 % for age 3 onwards	
Natural mortality	Fixed at 0.15 for all ages	
Stock weights	Equal to catch weights	
F plateau	Age 8	
Recruitment	Modelled as random walk	
Annual survey CV multiplier	Adjusted according to the number of survey hauls	Allows for greater variability when fewer hauls
Survey age CV multiplier: Aora	(2.4,2.0,1.8,1,1,1,1.8)	Allows for greater variability at younger & older ages
Survey age CV multiplier: Aora II	(2.4,2.0,1.8,1,1,1,1.8)	Allows for greater variability at younger & older ages
Survey age CV multiplier: Alba	(1.6,1.6,1,1,1,1.6,1.6)	Allows for greater variability at younger & older ages
F variability	1999: CV multiplier = 3.0	Allows greater variability in F in this year – sudden decrease in landings associated with ASP/PSP closures
Catch CV multiplier	(3.0,1.6,1,1,1,1,1.6,1.6)	Allows for greater variability at ages 3,4,9 & 10+
Down-weighting single points	Catch 1989, age 7, cv multiplier = 3 Alba 2010, age 3, cv multiplier = 3	Catch outlier Survey outlier

Table 3.9.5: West of Kintyre. Final TSA run parameter estimates.

Parameter	Notation	Description	2016
Initial fishing mortality	F(3, 1982)	Fishing mortality at age a in year y	0.077
	F(4, 1982)		0.130
	F(8, 1982)		0.320
Fishing mortality standard deviations	σ_F	Transitory changes in overall F	0
	σ_U	Persistent changes in selection (age effect in F)	0.089
	σ_V	Transitory changes in the year effect in F	0.284
	σ_Y	Persistent changes in the year effect in F	0
Measurement cv	cv_{catch}	Coefficient of variation of catch-at-age data	0.180
Recruitment		Log mean recruitment at start	2.115
	s_{rw}	Standard deviation of random walk	0.142
	cv_{rec}	Coefficient of variation of recruitment curve	0.080
Survey selectivities: Aora	$\Phi_{a1}(3)$	Survey selectivity at age a	0.647
	$\Phi_{a1}(4)$		1.168
	$\Phi_{a1}(5)$		1.368
	$\Phi_{a1}(6)$		1.369
	$\Phi_{a1}(7)$		1.365
	$\Phi_{a1}(8)$		1.337
	$\Phi_{a1}(9)$		1.202
Survey catchability standard deviations: Aora	$\sigma_{a1\Omega}$	Transitory changes in survey catchability	0.153
	$\sigma_{a1\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Aora	$\sigma_{a1survey}$	Coefficient of variation controlling gamma type dispersion	0.114
	$\eta_{a1survey}$	Coefficient of variation controlling poisson type dispersion	0.0006
Survey selectivities: Aora II	$\Phi_{a2}(3)$	Survey selectivity at age a	0.463
	$\Phi_{a2}(4)$		0.997
	$\Phi_{a2}(5)$		1.333
	$\Phi_{a2}(6)$		1.766
	$\Phi_{a2}(7)$		2.008
	$\Phi_{a2}(8)$		2.857
	$\Phi_{a2}(9)$		3.304

[1]Fixed parameter.

Survey catchability standard deviations: Aora II	$\sigma_{a2\Omega}$	Transitory changes in survey catchability	0.068
	$\sigma_{a2\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Aora II	$\sigma_{a2survey}$	Coefficient of variation controlling gamma type dispersion	0.150
	$\eta_{a2survey}$	Coefficient of variation controlling poisson type dispersion	0.010
Survey selectivities: Alba	$\Phi_a(3)$	Survey selectivity at age a	0.179
	Φ_a (4)		0.734
	Φ_a (5)		0.849
	Φ_a (6)		0.804
	Φ_a (7)		0.967
	Φ_a (8)		0.854
	Φ_a (9)		0.885
Survey catchability standard deviations: Alba	$\sigma_{a\Omega}$	Transitory changes in survey catchability	0.122
	$\sigma_{a\beta}$	Persistent changes in survey catchability	0[1]
Survey measurement coefficients of variation: Alba	$\sigma_{asurvey}$	Coefficient of variation controlling gamma type dispersion	0.181
	$\eta_{asurvey}$	Coefficient of variation controlling poisson type dispersion	0.010

[1] Fixed parameter.

Table 3.9.6: West of Kintyre. Estimated population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	9.541	8.984	7.264	6.458	5.558	4.350	3.559	6.953
1983	8.229	7.721	6.964	5.462	4.740	3.902	2.893	7.088
1984	7.486	6.591	5.801	5.064	3.869	3.162	2.471	6.315
1985	6.921	5.690	4.511	3.694	3.170	2.201	1.708	4.763
1986	6.627	5.526	4.268	3.254	2.611	2.158	1.430	4.205
1987	6.568	5.321	4.186	3.116	2.318	1.818	1.444	3.767
1988	5.148	5.169	3.845	2.893	2.106	1.545	1.166	3.348
1989	5.584	4.143	3.893	2.801	2.084	1.493	1.065	3.113
1990	9.056	4.528	3.105	2.840	2.037	1.492	1.054	2.947
1991	9.941	7.360	3.369	2.238	2.054	1.463	1.062	2.832
1992	11.968	8.087	5.500	2.436	1.607	1.475	1.042	2.761
1993	14.205	9.594	5.766	3.736	1.649	1.093	0.995	2.561
1994	15.124	11.588	6.887	3.923	2.517	1.112	0.738	2.400
1995	14.703	11.957	7.742	4.217	2.327	1.497	0.649	1.836
1996	14.282	12.150	8.936	5.547	2.960	1.623	1.046	1.738
1997	13.230	11.755	8.831	6.251	3.794	1.988	1.093	1.877
1998	11.630	11.025	8.535	6.154	4.264	2.521	1.322	1.977
1999	12.574	9.521	7.381	5.253	3.709	2.459	1.455	1.908
2000	12.149	10.465	7.052	5.081	3.619	2.488	1.636	2.237
2001	9.838	9.972	7.175	4.228	2.990	2.034	1.362	2.117
2002	13.617	8.138	7.216	4.641	2.655	1.818	1.180	2.016
2003	12.889	11.071	5.530	4.080	2.443	1.318	0.860	1.508
2004	13.711	10.539	7.509	3.292	2.297	1.272	0.642	1.159
2005	14.946	11.367	7.636	4.848	2.085	1.360	0.717	1.015
2006	15.254	12.492	8.516	5.222	3.206	1.318	0.829	1.055
2007	15.969	12.830	9.672	6.130	3.637	2.150	0.867	1.239
2008	19.590	13.395	9.860	6.906	4.145	2.341	1.370	1.343
2009	21.885	16.328	10.093	6.769	4.284	2.450	1.380	1.601
2010	21.678	18.385	12.731	7.288	4.465	2.698	1.520	1.852
2011	20.294	18.422	14.857	9.594	5.127	3.020	1.779	2.227
2012	19.893	17.109	14.759	11.043	6.600	3.312	1.827	2.432
2013	17.861	16.539	12.881	9.888	6.313	3.258	1.476	1.905
2014	16.427	15.071	13.235	9.577	6.708	3.908	1.858	1.937
2015	17.482	13.747	11.715	9.310	5.926	3.640	1.882	1.836
2016	15.940	14.766	11.052	8.770	6.431	3.761	2.161	2.213

Table 3.9.7: West of Kintyre. Standard errors of estimates of population abundance by age and year (in millions) from the final TSA run.

	3	4	5	6	7	8	9	10+
1982	0.796	0.827	0.516	0.524	0.545	0.486	0.730	1.357
1983	0.770	0.636	0.627	0.393	0.388	0.392	0.336	0.965
1984	0.720	0.602	0.473	0.470	0.292	0.281	0.273	0.726
1985	0.683	0.533	0.416	0.336	0.328	0.198	0.185	0.568
1986	0.587	0.545	0.408	0.320	0.260	0.245	0.149	0.515
1987	0.511	0.471	0.422	0.316	0.246	0.197	0.181	0.464
1988	0.401	0.399	0.355	0.322	0.235	0.182	0.145	0.434
1989	0.388	0.318	0.308	0.273	0.248	0.180	0.138	0.401
1990	0.532	0.306	0.241	0.236	0.208	0.178	0.136	0.370
1991	0.587	0.417	0.232	0.181	0.179	0.157	0.134	0.337
1992	0.658	0.460	0.313	0.174	0.135	0.134	0.118	0.315
1993	0.736	0.510	0.321	0.221	0.121	0.095	0.096	0.284
1994	0.815	0.580	0.362	0.229	0.159	0.087	0.069	0.255
1995	0.844	0.620	0.392	0.239	0.150	0.113	0.061	0.207
1996	0.885	0.684	0.468	0.293	0.175	0.111	0.085	0.188
1997	0.874	0.703	0.486	0.332	0.210	0.127	0.083	0.183
1998	0.808	0.688	0.484	0.353	0.236	0.153	0.095	0.182
1999	0.823	0.615	0.426	0.313	0.223	0.154	0.108	0.181
2000	0.753	0.662	0.431	0.302	0.225	0.164	0.119	0.213
2001	0.573	0.588	0.432	0.276	0.199	0.150	0.117	0.223
2002	0.785	0.461	0.422	0.298	0.189	0.137	0.106	0.231
2003	0.784	0.638	0.319	0.270	0.194	0.121	0.092	0.211
2004	0.887	0.638	0.425	0.190	0.162	0.117	0.075	0.179
2005	0.939	0.733	0.456	0.284	0.125	0.108	0.079	0.159
2006	0.885	0.781	0.540	0.319	0.198	0.087	0.076	0.150
2007	0.855	0.743	0.598	0.405	0.240	0.148	0.067	0.151
2008	0.993	0.714	0.552	0.439	0.296	0.175	0.110	0.145
2009	1.146	0.827	0.527	0.399	0.311	0.210	0.130	0.172
2010	1.464	0.963	0.644	0.403	0.284	0.221	0.154	0.207
2011	1.316	1.225	0.753	0.491	0.287	0.202	0.160	0.242
2012	1.489	1.098	0.941	0.583	0.373	0.219	0.151	0.260
2013	1.721	1.233	0.809	0.656	0.401	0.248	0.140	0.229
2014	2.163	1.456	0.997	0.637	0.481	0.293	0.181	0.253
2015	2.657	1.820	1.169	0.780	0.478	0.344	0.217	0.278
2016	3.285	2.257	1.511	0.971	0.649	0.399	0.277	0.375

Table 3.9.8: 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	0.062	0.108	0.129	0.154	0.202	0.254	0.254	0.254
1983	0.077	0.139	0.171	0.186	0.251	0.308	0.308	0.308
1984	0.126	0.229	0.302	0.324	0.414	0.468	0.468	0.468
1985	0.075	0.138	0.178	0.197	0.238	0.285	0.285	0.285
1986	0.070	0.131	0.168	0.192	0.215	0.258	0.258	0.258
1987	0.087	0.169	0.217	0.243	0.259	0.298	0.298	0.298
1988	0.065	0.133	0.166	0.178	0.195	0.225	0.225	0.225
1989	0.063	0.137	0.170	0.175	0.188	0.204	0.204	0.204
1990	0.059	0.141	0.175	0.177	0.184	0.192	0.192	0.192
1991	0.055	0.145	0.178	0.184	0.185	0.193	0.193	0.193
1992	0.066	0.191	0.242	0.248	0.245	0.250	0.250	0.250
1993	0.060	0.182	0.236	0.246	0.246	0.245	0.245	0.245
1994	0.082	0.255	0.341	0.372	0.368	0.390	0.390	0.390
1995	0.043	0.142	0.184	0.204	0.211	0.210	0.210	0.210
1996	0.047	0.169	0.205	0.230	0.249	0.246	0.246	0.246
1997	0.045	0.173	0.212	0.230	0.259	0.258	0.258	0.258
1998	0.063	0.253	0.337	0.358	0.402	0.400	0.400	0.400
1999	0.037	0.153	0.225	0.224	0.250	0.259	0.259	0.259
2000	0.055	0.230	0.362	0.381	0.427	0.454	0.454	0.454
2001	0.041	0.173	0.287	0.315	0.348	0.394	0.394	0.394
2002	0.056	0.250	0.420	0.477	0.538	0.588	0.588	0.588
2003	0.051	0.238	0.372	0.423	0.493	0.561	0.561	0.561
2004	0.037	0.172	0.288	0.308	0.374	0.420	0.420	0.420
2005	0.030	0.139	0.231	0.264	0.309	0.346	0.346	0.346
2006	0.023	0.107	0.179	0.213	0.251	0.269	0.269	0.269
2007	0.024	0.109	0.187	0.243	0.291	0.302	0.302	0.302
2008	0.030	0.125	0.225	0.328	0.376	0.379	0.379	0.379
2009	0.024	0.098	0.175	0.267	0.313	0.328	0.328	0.328
2010	0.018	0.071	0.132	0.194	0.234	0.267	0.267	0.267
2011	0.020	0.076	0.147	0.222	0.286	0.352	0.352	0.352
2012	0.034	0.123	0.250	0.408	0.554	0.657	0.657	0.657
2013	0.020	0.072	0.144	0.237	0.328	0.412	0.412	0.412
2014	0.028	0.103	0.202	0.329	0.462	0.584	0.584	0.584
2015	0.019	0.069	0.141	0.222	0.307	0.376	0.376	0.376
2016	0.026	0.095	0.195	0.307	0.425	0.519	0.519	0.519

Table 3.9.9: 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	0.009	0.015	0.016	0.020	0.026	0.032	0.032	0.032
1983	0.012	0.020	0.022	0.025	0.034	0.041	0.041	0.041
1984	0.021	0.032	0.037	0.040	0.053	0.059	0.059	0.059
1985	0.014	0.021	0.024	0.027	0.033	0.039	0.039	0.039
1986	0.013	0.020	0.023	0.026	0.030	0.035	0.035	0.035
1987	0.017	0.026	0.029	0.032	0.036	0.040	0.040	0.040
1988	0.013	0.021	0.022	0.025	0.028	0.031	0.031	0.031
1989	0.013	0.022	0.023	0.024	0.031	0.029	0.029	0.029
1990	0.012	0.022	0.023	0.024	0.026	0.028	0.028	0.028
1991	0.011	0.022	0.024	0.024	0.025	0.027	0.027	0.027
1992	0.013	0.029	0.030	0.032	0.032	0.033	0.033	0.033
1993	0.012	0.027	0.030	0.031	0.032	0.031	0.031	0.031
1994	0.016	0.037	0.040	0.044	0.045	0.047	0.047	0.047
1995	0.009	0.022	0.024	0.026	0.028	0.027	0.027	0.027
1996	0.010	0.025	0.026	0.029	0.032	0.031	0.031	0.031
1997	0.009	0.026	0.027	0.029	0.033	0.033	0.033	0.033
1998	0.013	0.036	0.040	0.042	0.046	0.048	0.048	0.048
1999	0.007	0.023	0.028	0.029	0.032	0.033	0.033	0.033
2000	0.011	0.033	0.043	0.045	0.050	0.053	0.053	0.053
2001	0.008	0.026	0.035	0.039	0.043	0.047	0.047	0.047
2002	0.011	0.036	0.048	0.055	0.062	0.067	0.067	0.067
2003	0.010	0.034	0.043	0.049	0.059	0.065	0.065	0.065
2004	0.008	0.025	0.035	0.038	0.046	0.051	0.051	0.051
2005	0.006	0.021	0.029	0.033	0.039	0.043	0.043	0.043
2006	0.005	0.017	0.023	0.028	0.033	0.035	0.035	0.035
2007	0.005	0.017	0.024	0.032	0.038	0.039	0.039	0.039
2008	0.006	0.019	0.028	0.041	0.048	0.048	0.048	0.048
2009	0.005	0.015	0.022	0.034	0.041	0.042	0.042	0.042
2010	0.004	0.011	0.017	0.025	0.031	0.035	0.035	0.035
2011	0.004	0.012	0.019	0.029	0.037	0.045	0.045	0.045
2012	0.008	0.019	0.030	0.047	0.064	0.077	0.077	0.077
2013	0.005	0.012	0.019	0.031	0.044	0.057	0.057	0.057
2014	0.007	0.018	0.028	0.045	0.063	0.083	0.083	0.083
2015	0.005	0.014	0.024	0.037	0.051	0.063	0.063	0.063
2016	0.009	0.031	0.062	0.097	0.134	0.167	0.167	0.167

Table 3.9.10: West of Kintyre. Stock summary from the final TSA run. Catch estimate and Mean F in 2016 are model forecasts.

	Catch (t)	Catch estimate (t)	SSB (t)	Recruitment (1000s)	Mean F(4-6)
1982	1651	1386	9407	9541	0.130
1983	1443	1379	7728	8229	0.165
1984	1857	2041	7647	7486	0.285
1985	1032	976	5898	6921	0.171
1986	836	793	5127	6627	0.164
1987	1044	922	5074	6568	0.209
1988	598	599	4214	5148	0.159
1989	553	577	4271	5584	0.161
1990	694	603	4811	9056	0.164
1991	704	660	5372	9941	0.169
1992	890	859	5537	11968	0.227
1993	1133	979	6519	14205	0.222
1994	1291	1495	7216	15124	0.323
1995	1001	941	7691	14703	0.177
1996	1363	1152	7976	14282	0.201
1997	1602	1276	8435	13230	0.205
1998	1794	1820	8007	11630	0.316
1999	1348	1121	7634	12574	0.200
2000	1721	1741	7584	12149	0.324
2001	1250	1300	6658	9838	0.258
2002	1453	1703	6888	13617	0.382
2003	1551	1425	6394	12889	0.344
2004	1170	1110	6647	13711	0.256
2005	1165	1068	7488	14946	0.211
2006	908	926	7503	15254	0.166
2007	1108	1179	8892	15969	0.180
2008	1540	1592	9750	19590	0.226
2009	1386	1242	9807	21885	0.180
2010	1478	1125	11239	21678	0.132
2011	1382	1396	11307	20294	0.148
2012	2428	2511	11520	19893	0.261
2013	1715	1625	11431	17861	0.151
2014	2385	2189	11054	16427	0.211
2015	1412	1379	9997	17482	0.144
2016	NA	1956	10451	15940	0.199

7 Figures

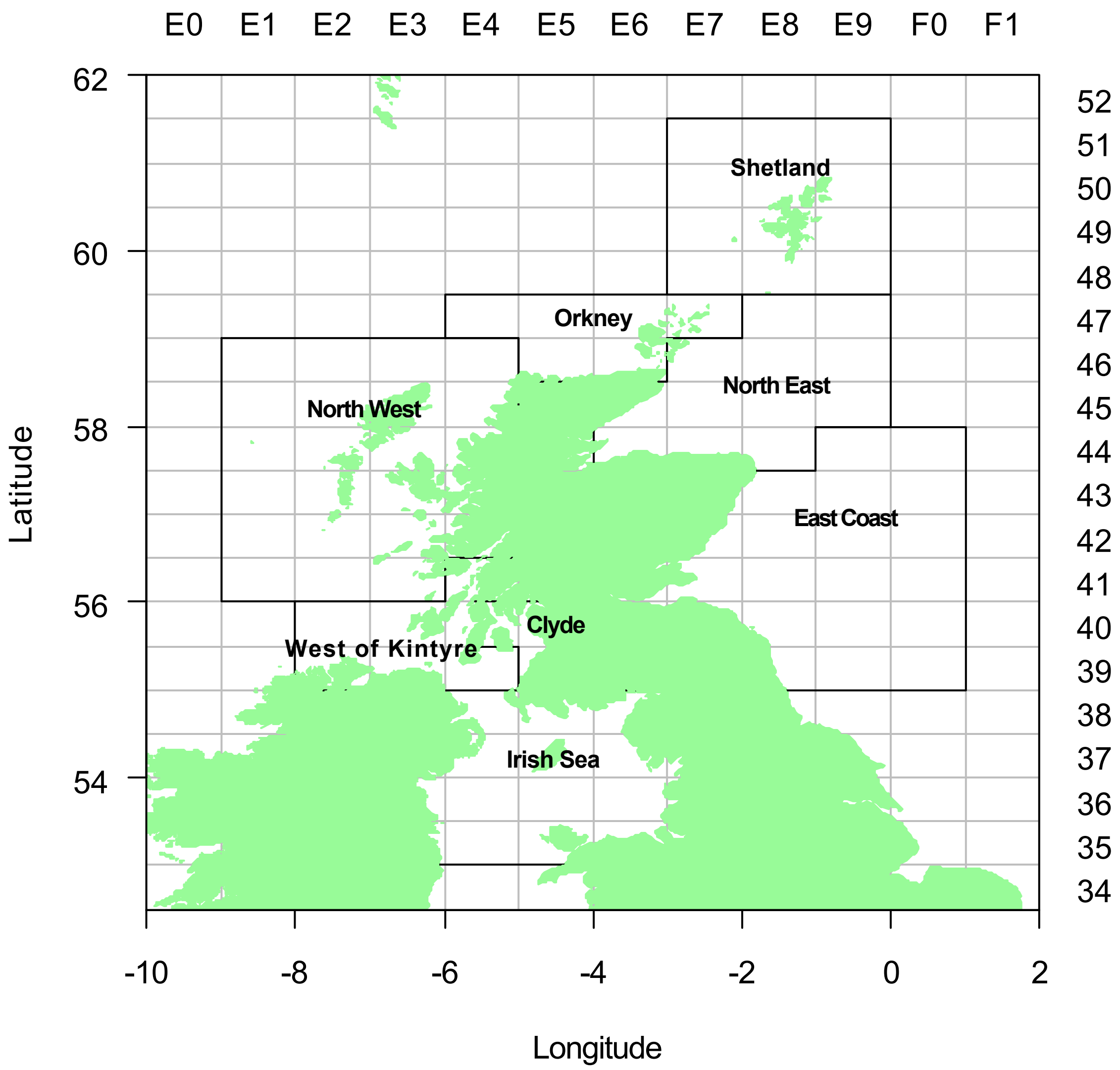

Figure 2.1.1: Scottish scallop assesment areas

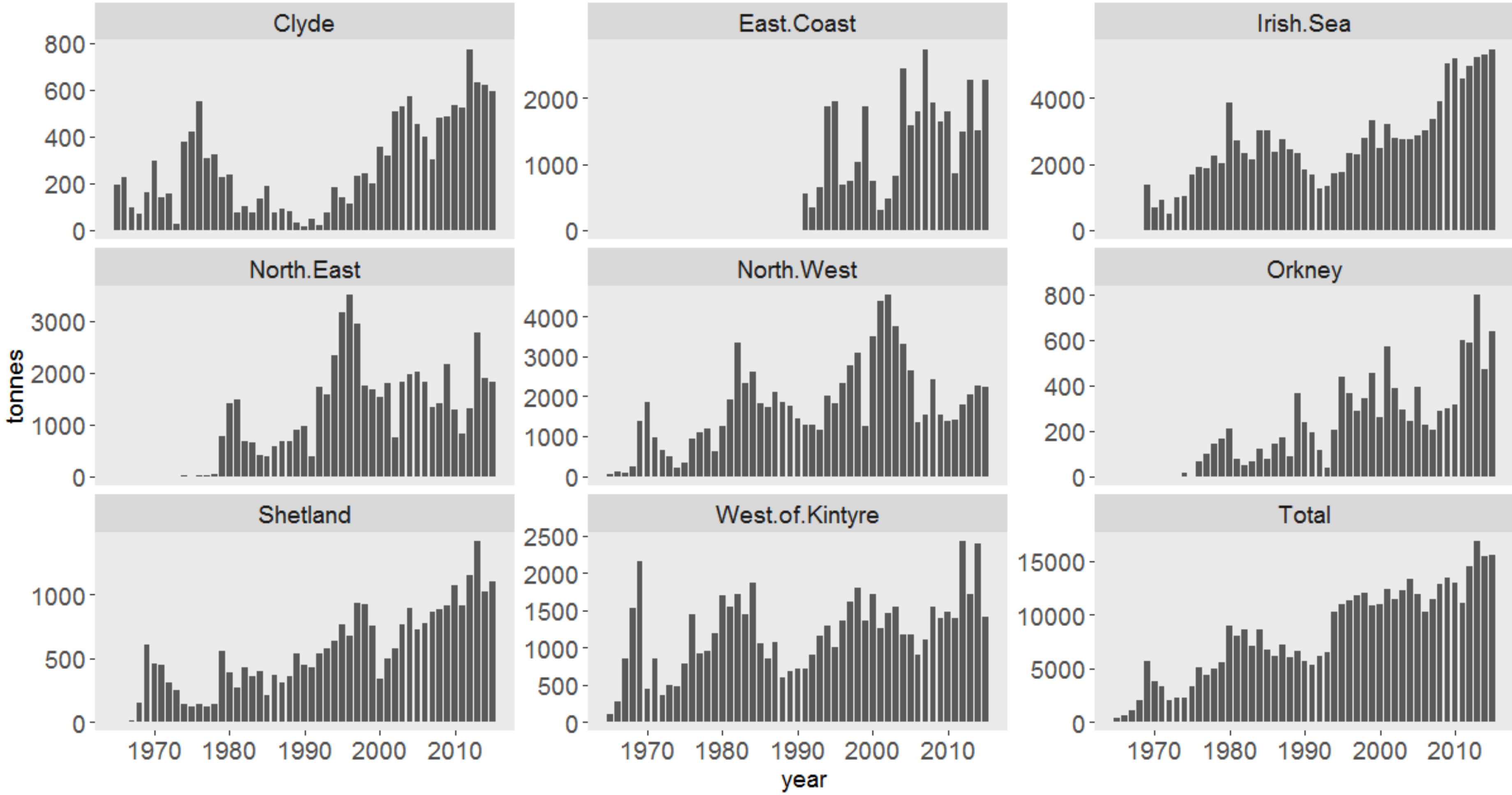

Figure 3.1.1: Total reported landings by assessment area (tonnes). Some UK (non Scotland) landings pre 2000 may have been taken elsewhere in Division VIIa (i.e. out-with the Irish Sea assessment area). Note differences in scales of landings plots.

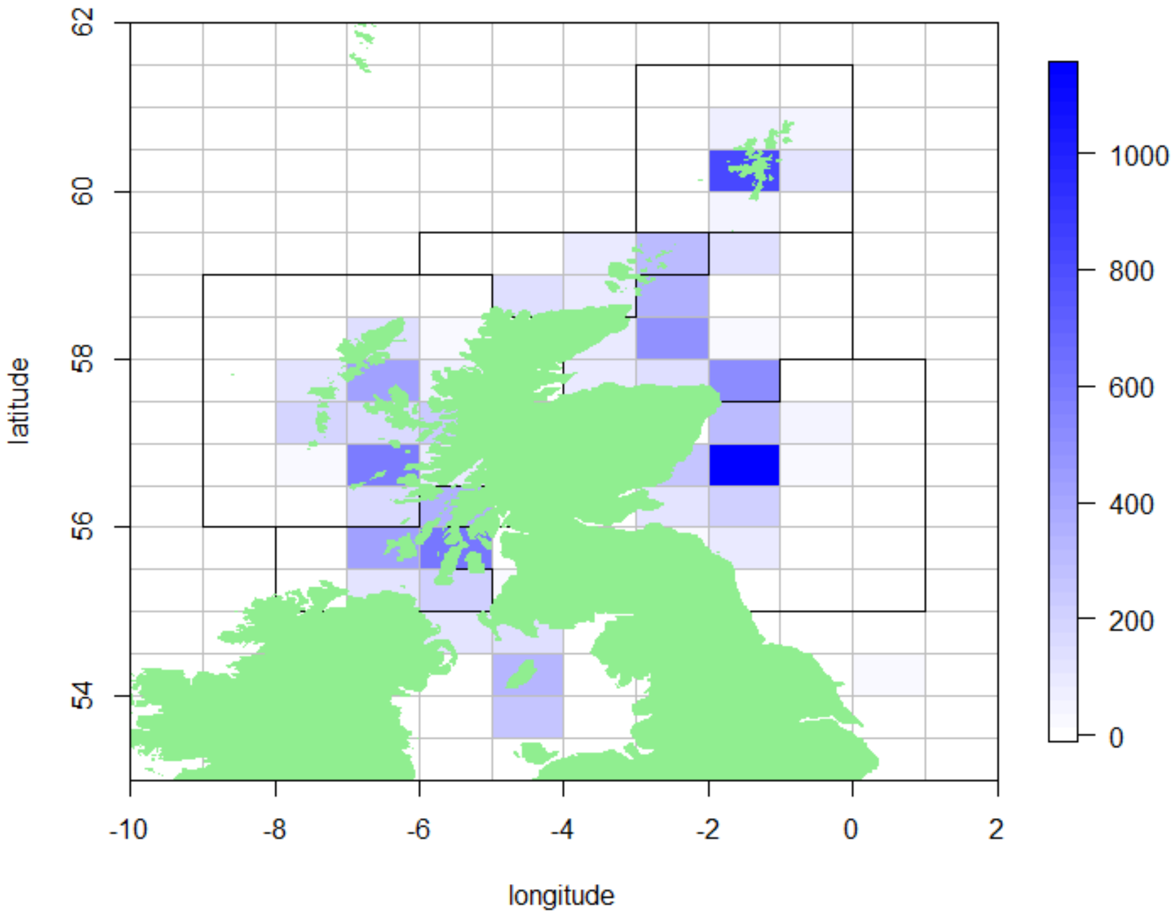

Figure 3.1.2: Spatial distribution of scallop landings (tonnes) into Scotland in 2015.

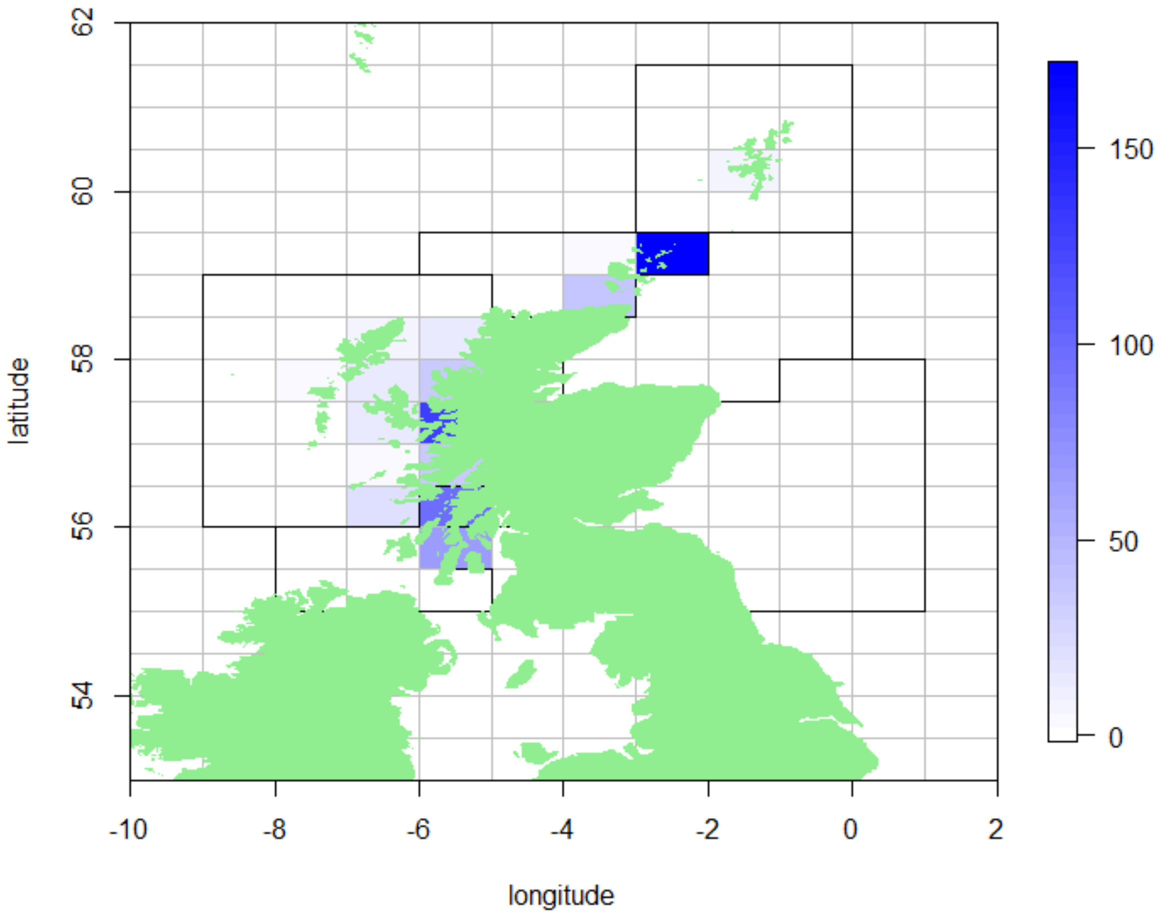

Figure 3.1.3: Spatial distribution of dive caught scallop landings (tonnes) into Scotland in 2015.

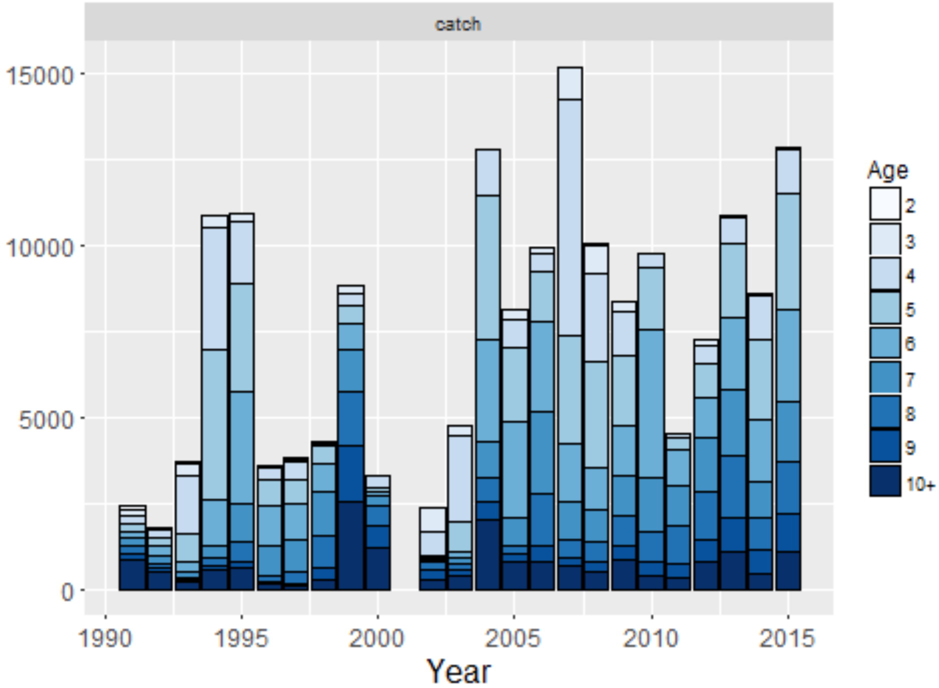

Figure 3.3.1: East Coast. Total catch-at-age numbers (in thousands).

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

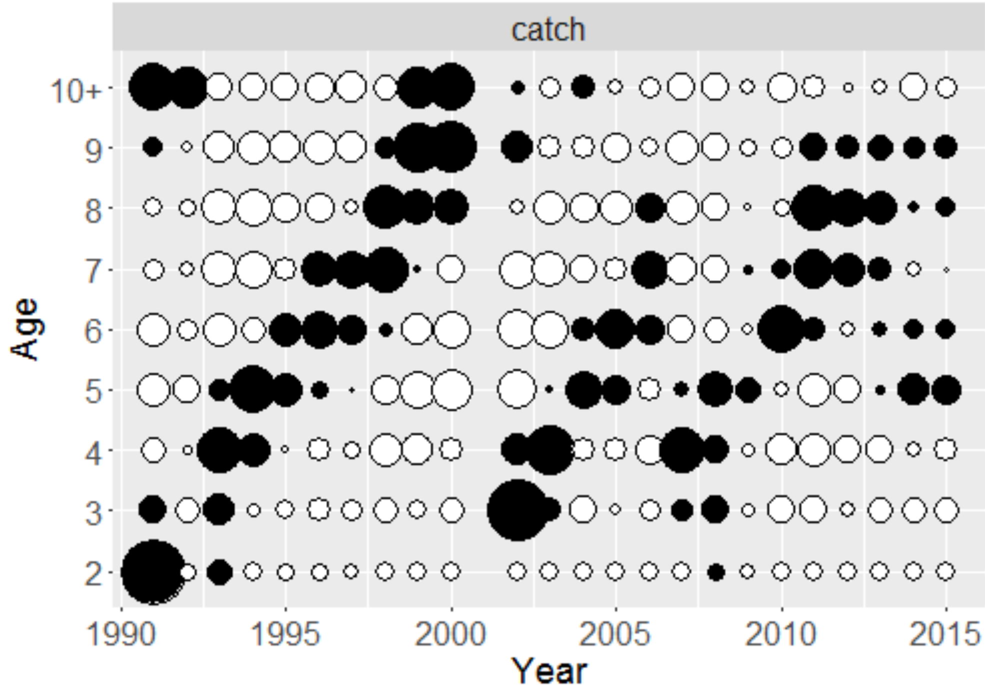

Figure 3.3.3: East Coast. Catch at age (by proportion): mean standardised over time by age class. Dark shaded circles represent above average values and white circles below average.

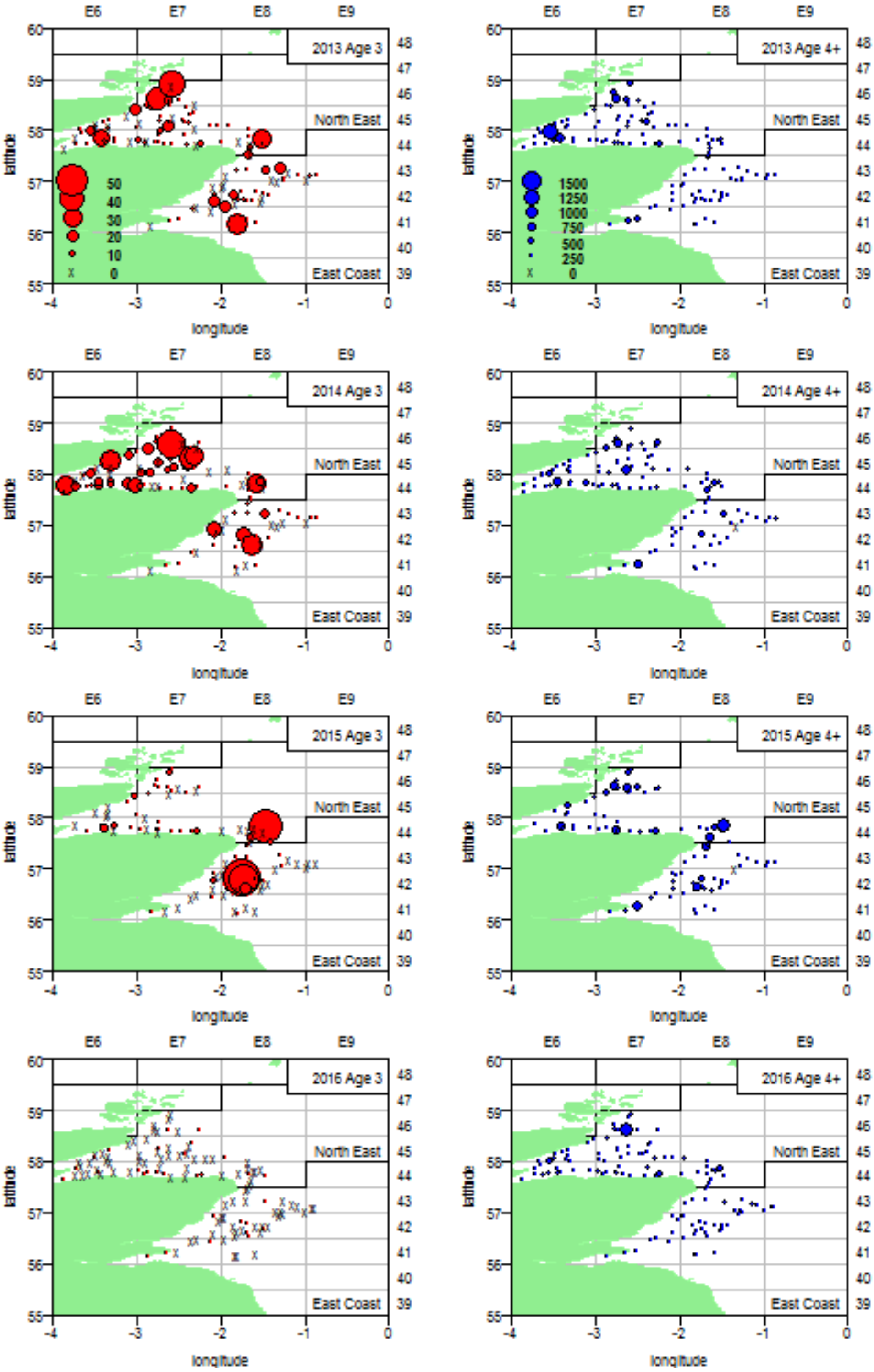

Figure 3.3.4: North Sea survey. Distribution of dredge survey catch rates (2013-2016).

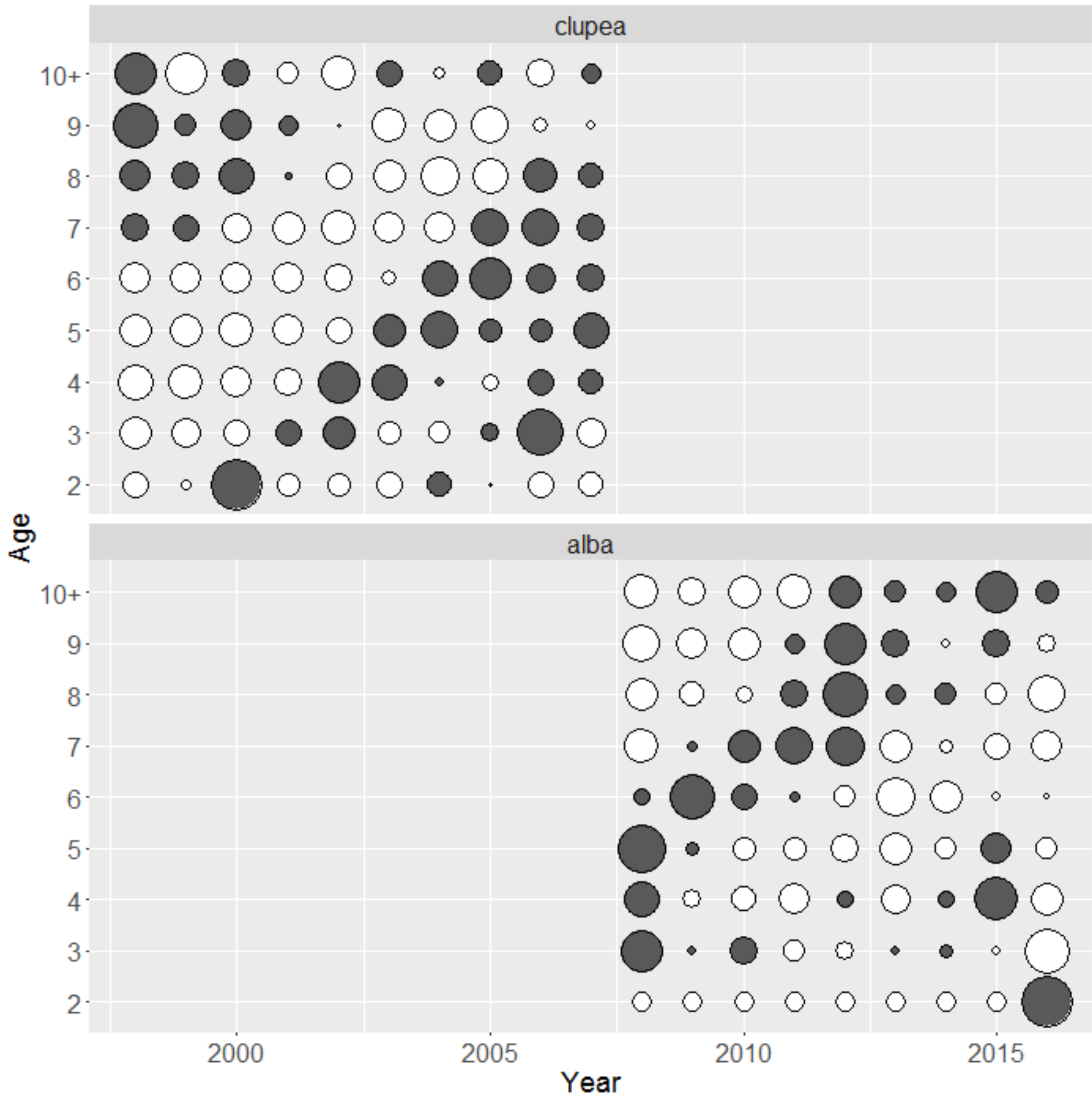

Figure 3.3.5: East Coast. Mean standardised survey catch at age. Dark shaded circles represent above average values and white circles below average.

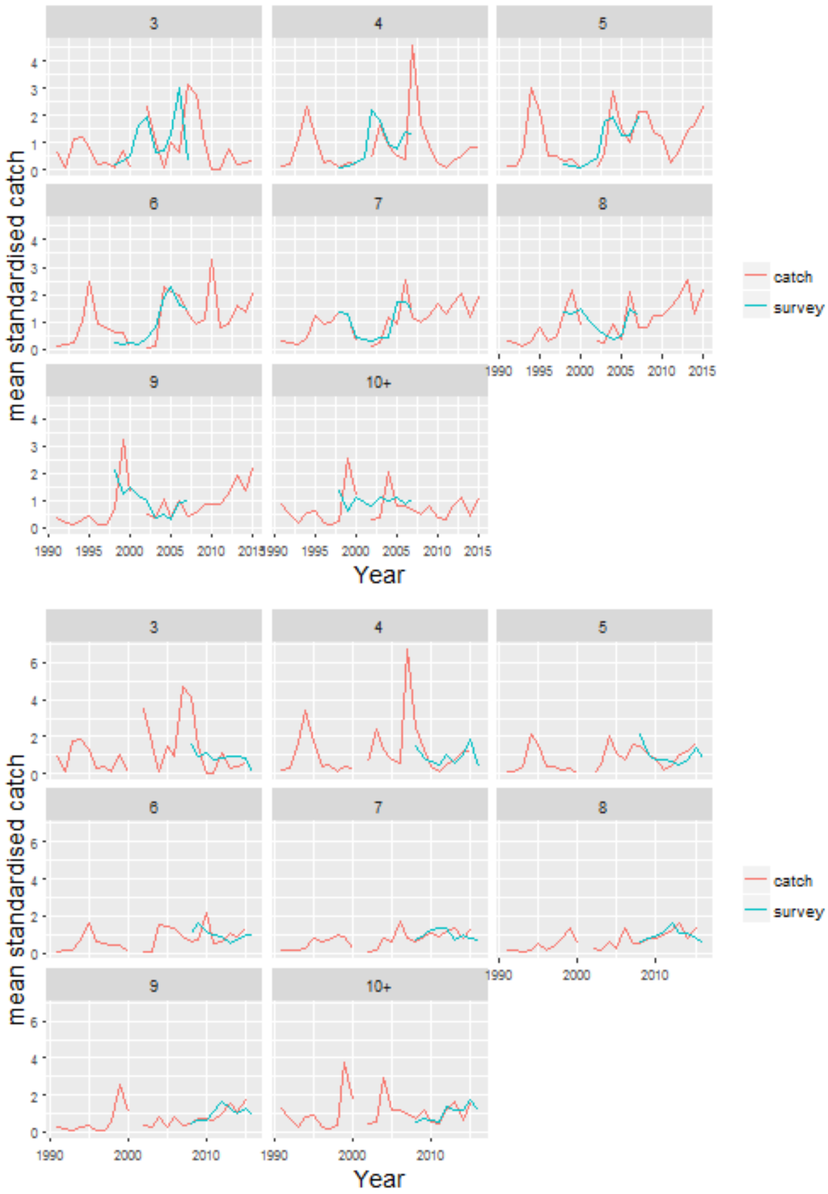

Figure 3.3.6: East Coast. Mean standardised survey and commercial catch at age comparison. Upper plot: Clupea survey, lower plot: Alba survey.

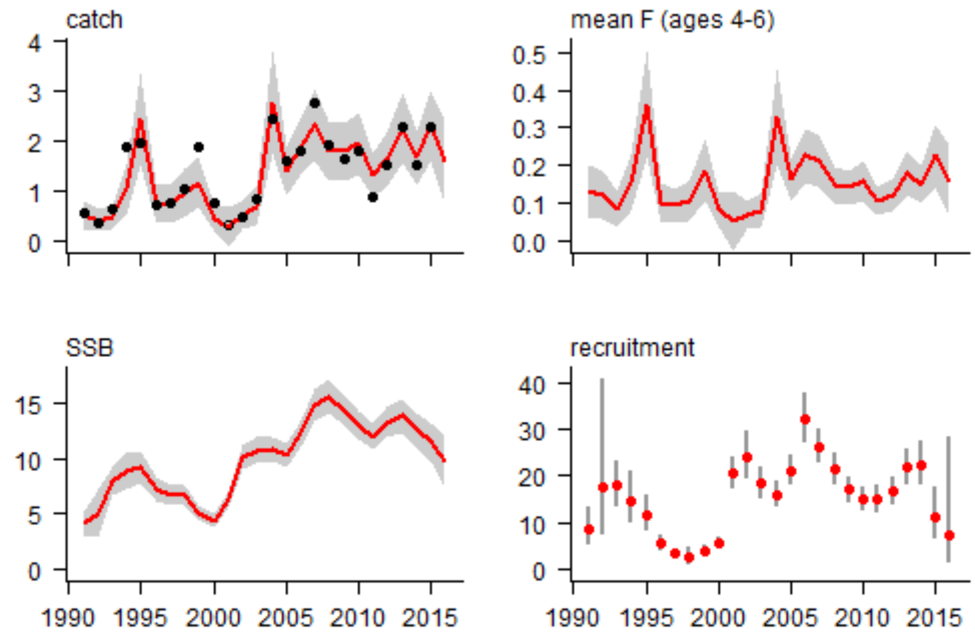

Figure 3.3.7: East Coast. TSA stock summaries from the final TSA run. Catch and SSB are in terms of live weight (thousand tonnes) and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals. Unfilled circle (catch data): data not included in the assessment.

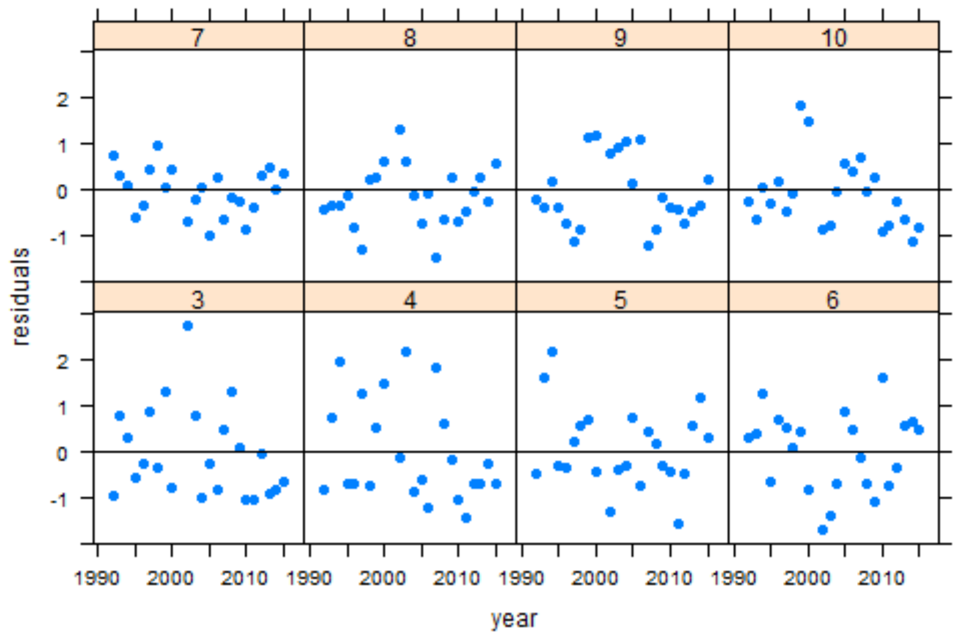

Figure 3.3.8: East Coast. Standardised catch residuals by age from the final TSA run.

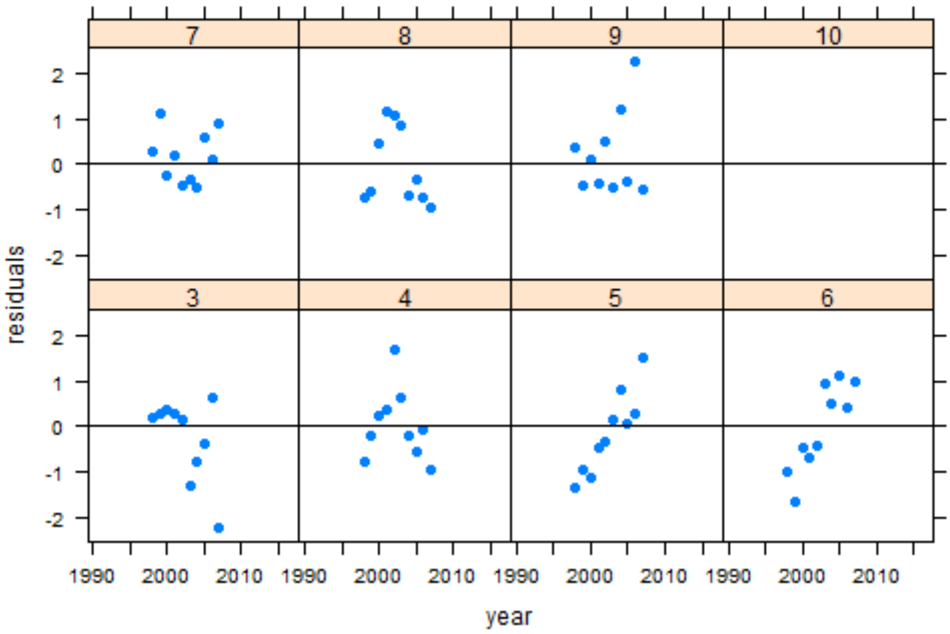

Figure 3.3.9: East Coast. Standardised survey residuals by age for the Clupea survey from the final TSA run.

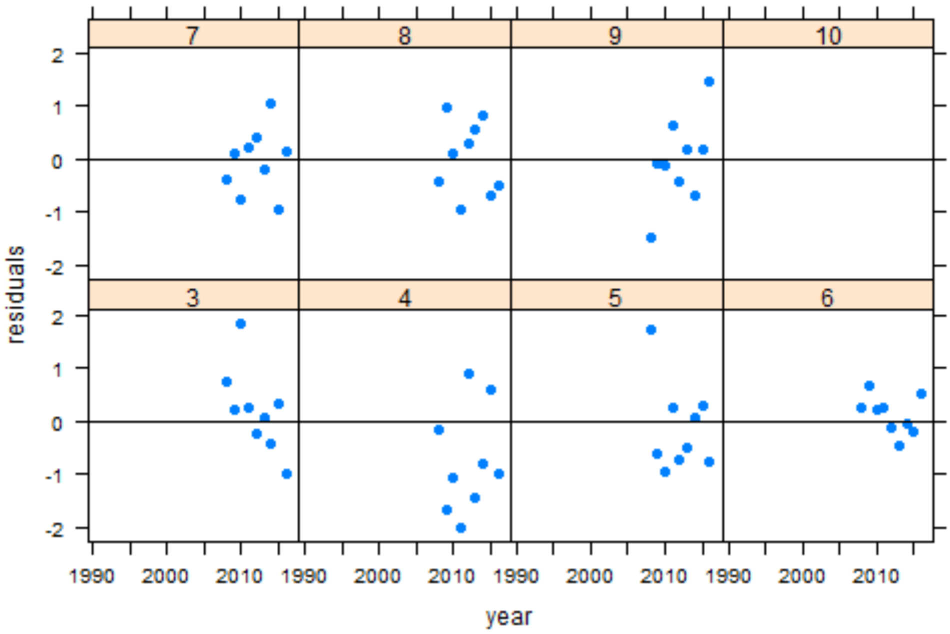

Figure 3.3.10: East Coast. Standardised survey residuals by age for the Alba survey from the final TSA run.

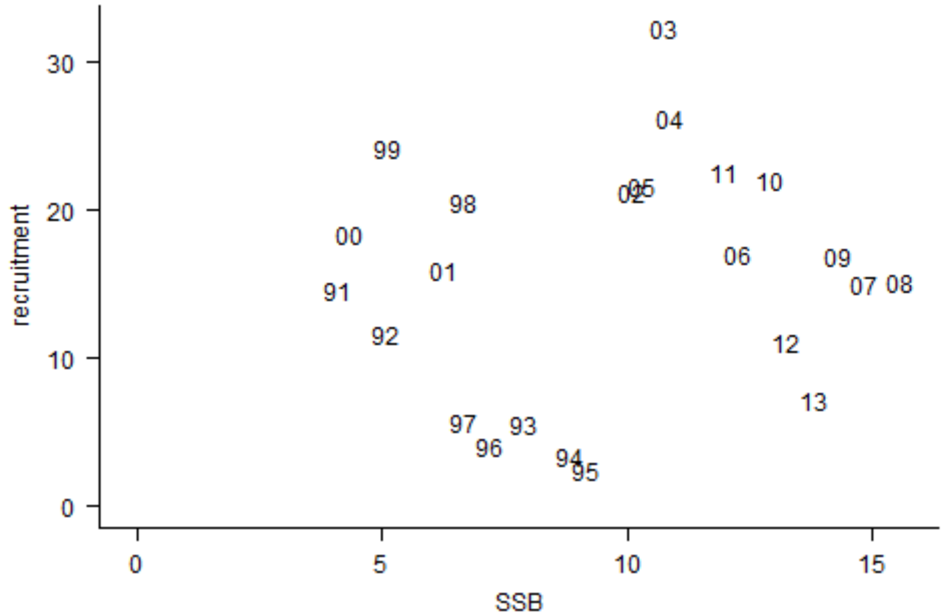

Figure 3.3.11: East Coast. Stock-recruit plot from the final TSA run. Recruitment (age 3) is in millions and SSB in thousand tonnes. Values are labelled with year class.

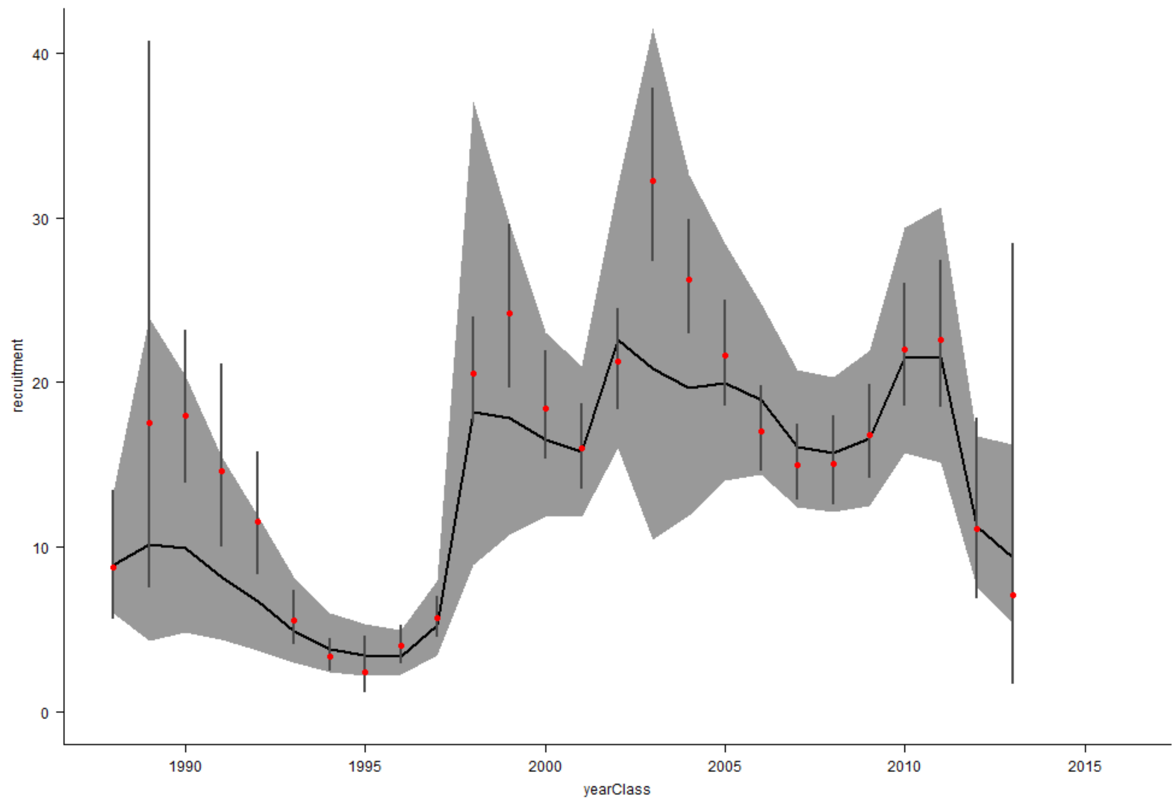

Figure 3.3.12: East Coast. Estimated recruitment time-series from the final TSA assessment. Red points give estimated values with grey bars indicating approximate pointwise 95% confidence intervals. The black line (also with 95% CI) shows the underlying random-walk recruitment model estimated by TSA.

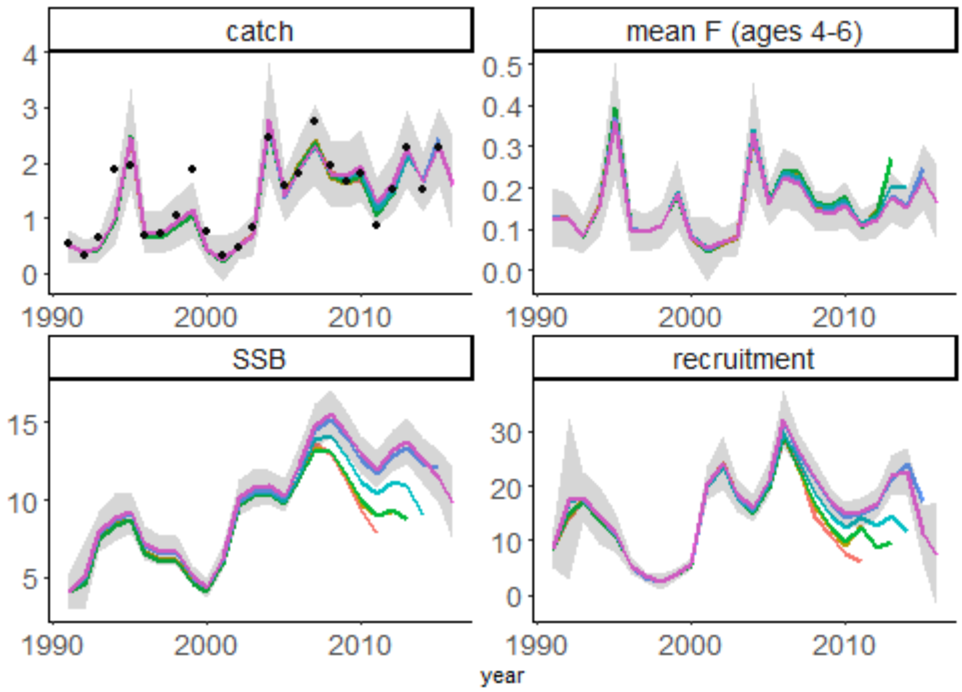

Figure 3.3.13: East Coast. Estimates of catch, mean $F_{4\text{-}6}$, SSB and recruitment with final run 95 % confidence intervals (grey shading) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment (age 3) in millions.

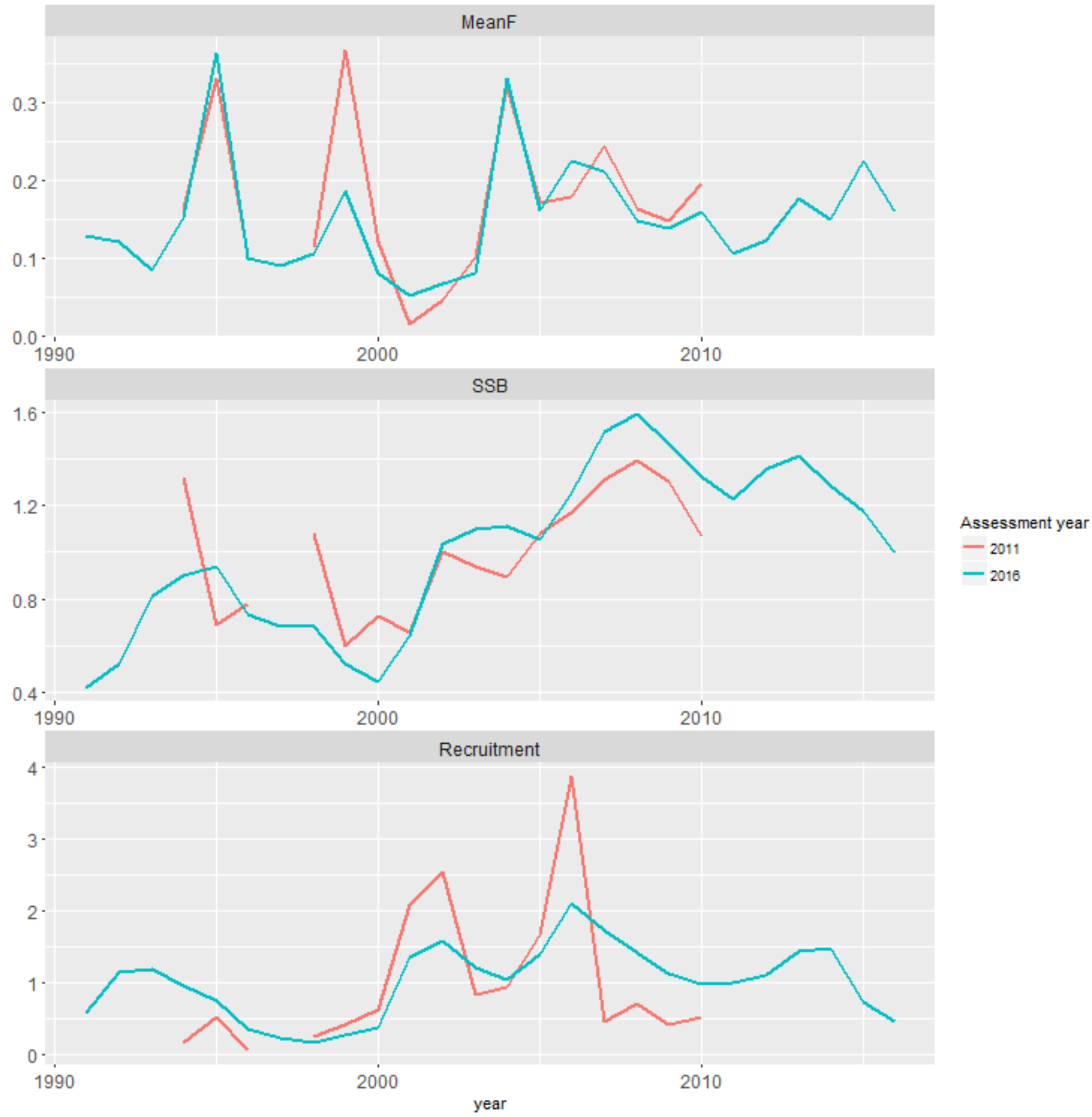

Figure 3.3.14: East Coast. Comparison of final assessment results with previous empirical survey based assessment conducted in 2011. Recruitment and SSB are mean standardised (over the common time period) to allow for comparison between results in live weight (current assessment) and survey indices (2011 assessment).

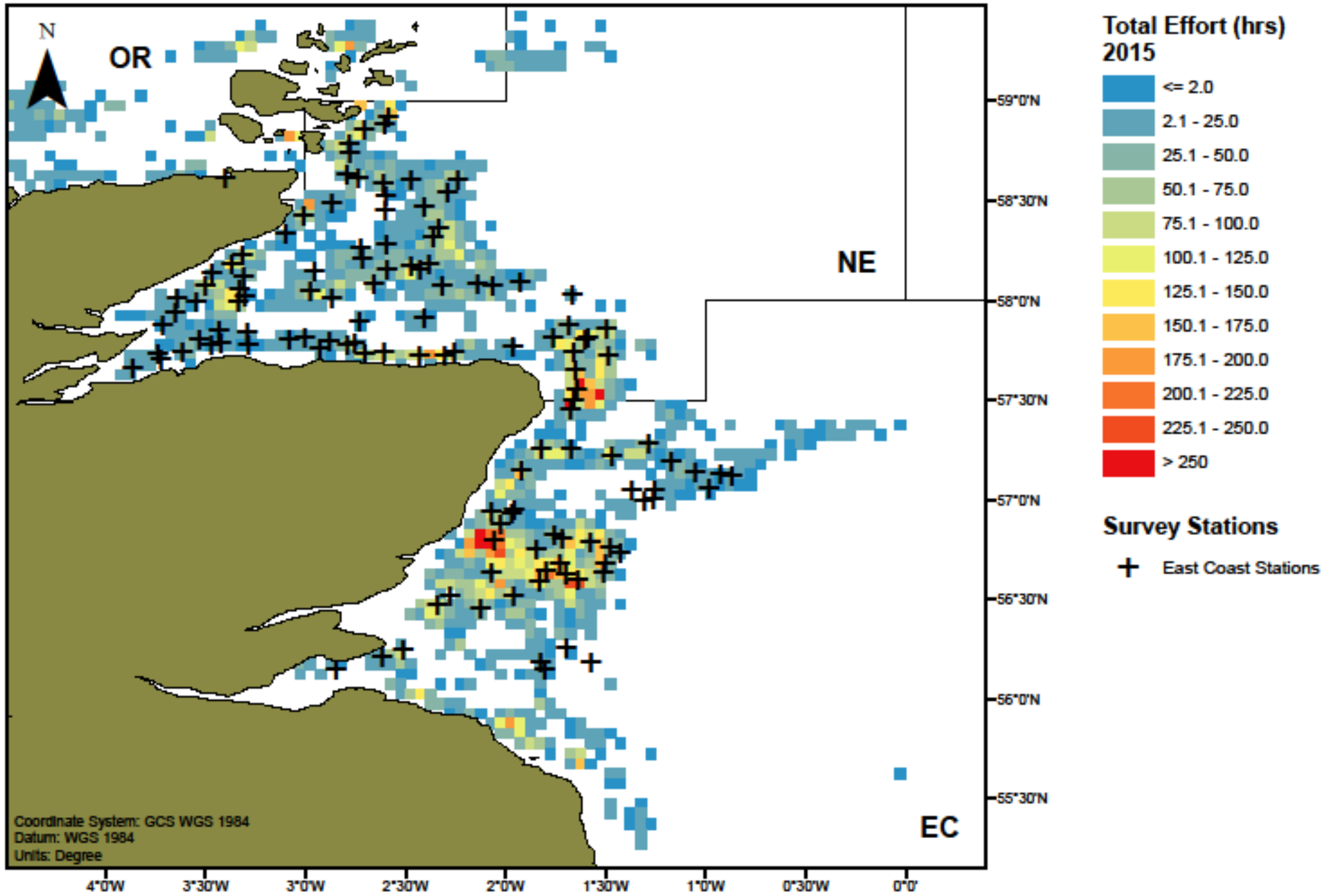

Figure 3.3.15: North Sea survey. VMS effort intensity (UK vessels) overlaid with survey station locations (shown as crosses).

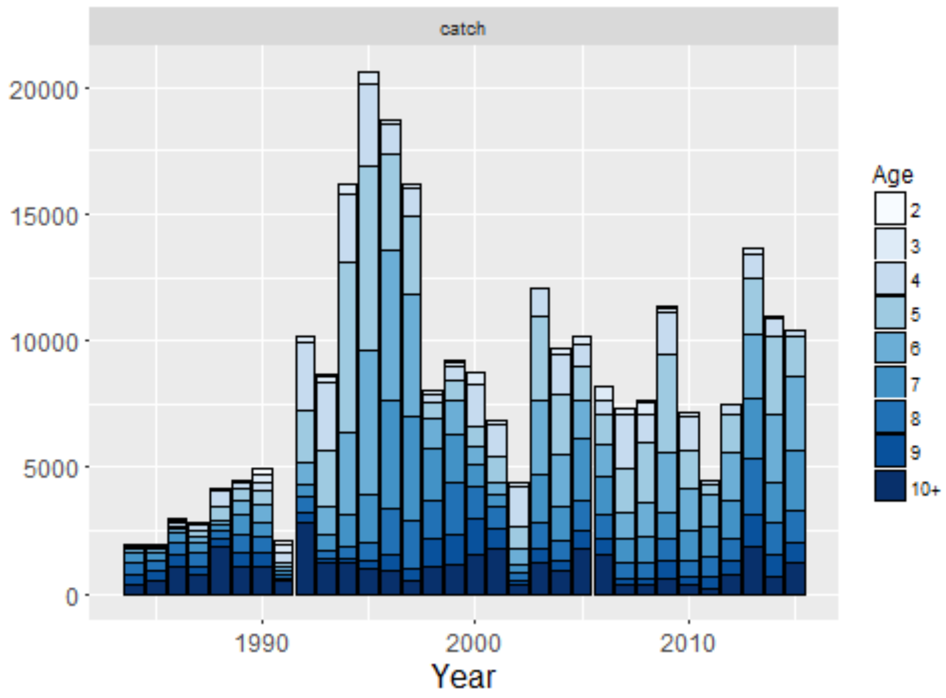

Figure 3.5.1: North East. Total catch-at-age numbers (in thousands).

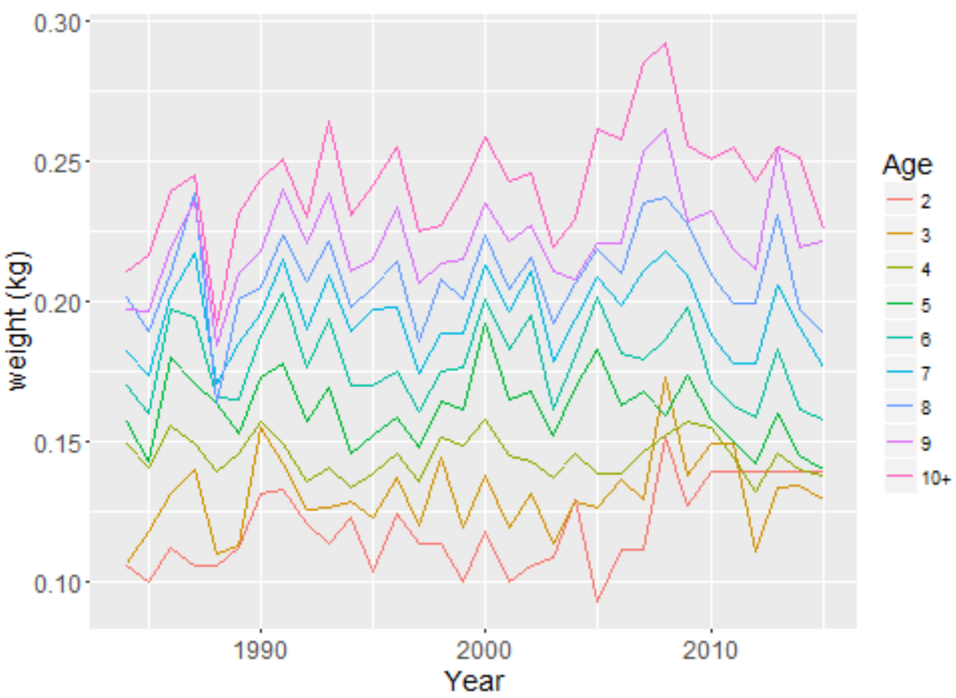

Figure 3.5.2: North East. Mean weights-at-age (kg) in total catch (also used for stock weights).

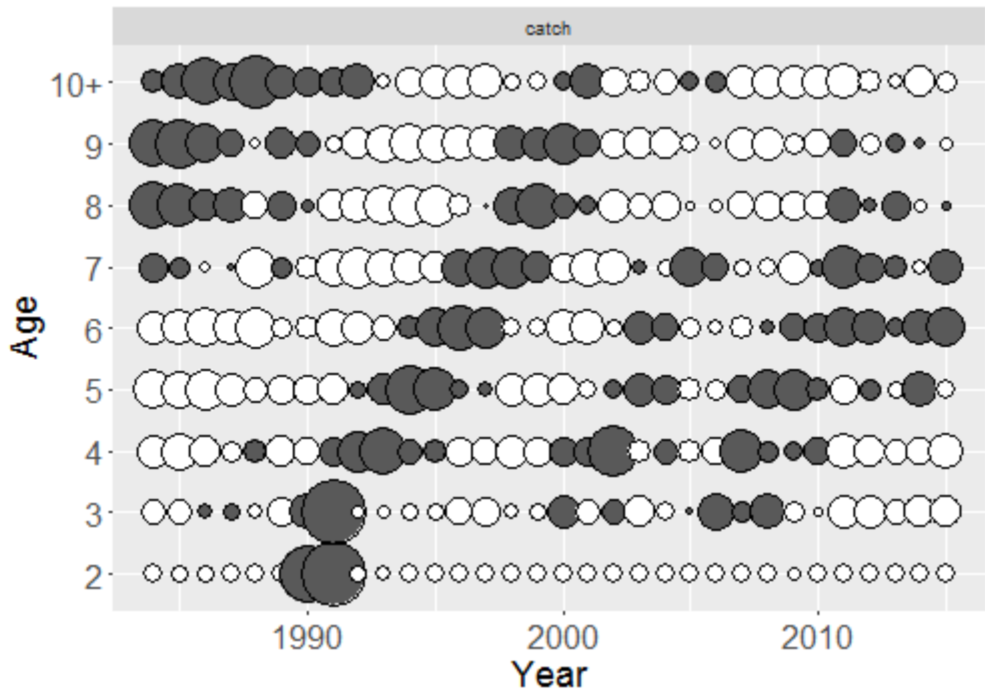

Figure 3.5.3: North East. Catch at age (by proportion): mean standardised over time by age class. Dark shaded circles represent above average values and white circles below average.

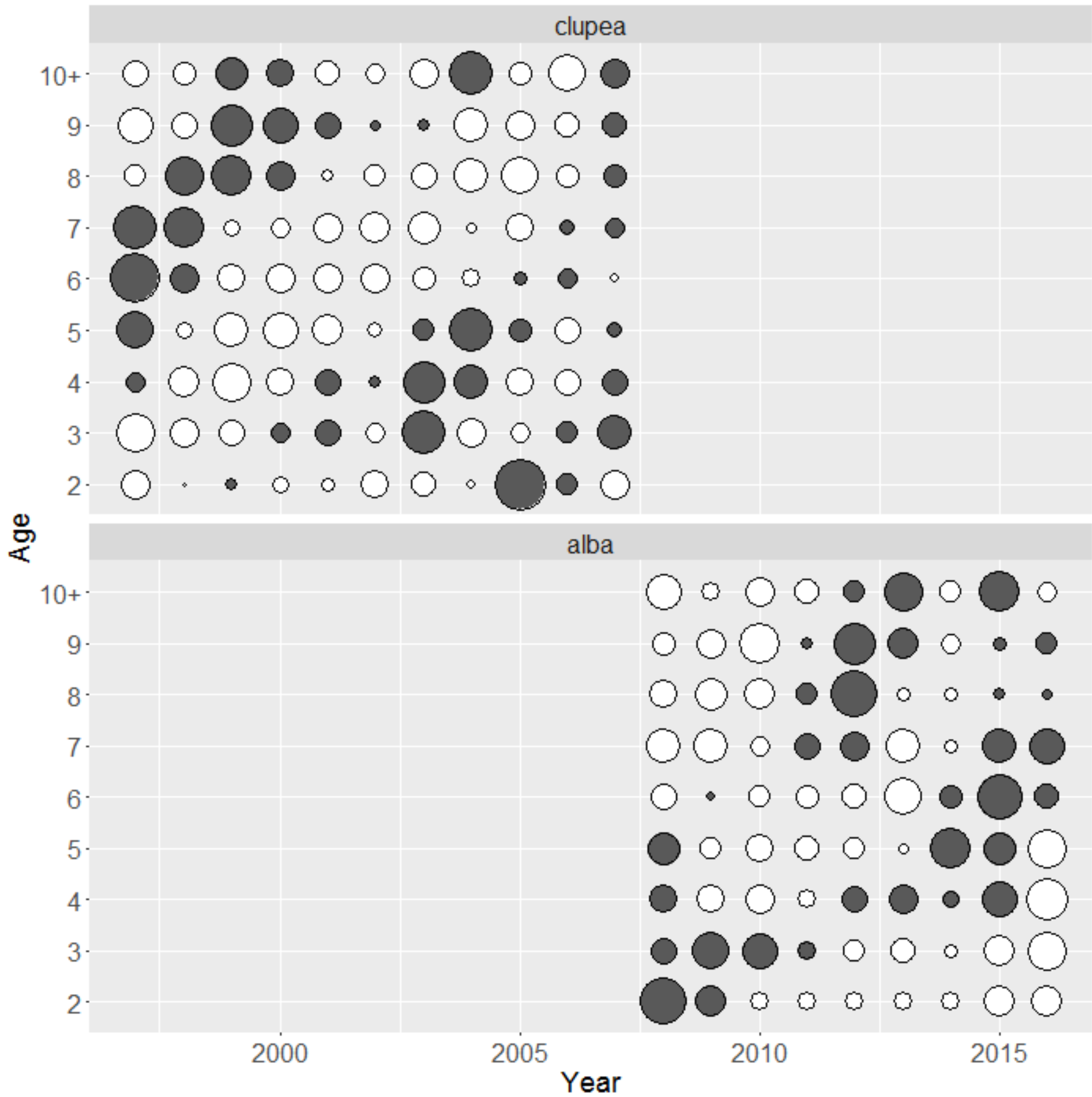

Figure 3.5.4: North East. Mean standardised survey catch at age. Dark shaded circles represent above average values and white circles below average.

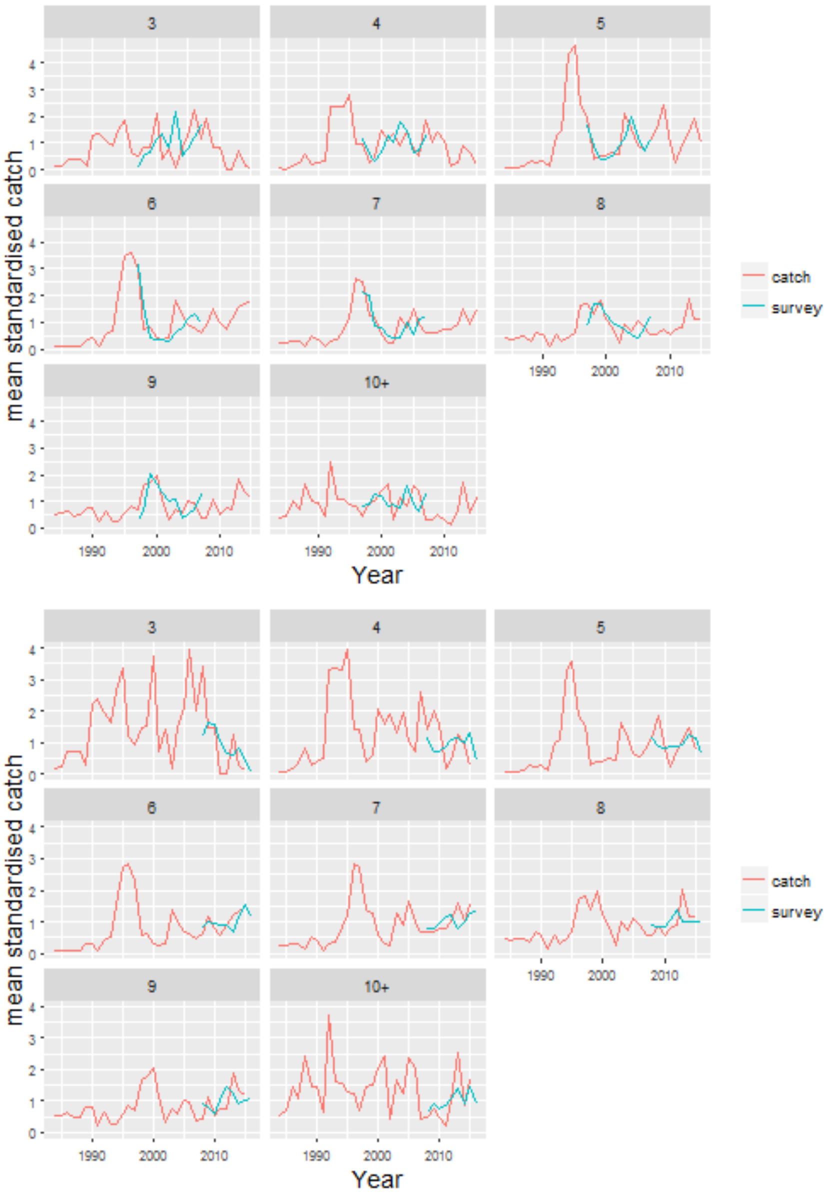

Figure 3.5.5: North East. Mean standardised survey and commercial catch at age comparison. Upper plot: Clupea survey, lower plot: Alba survey.

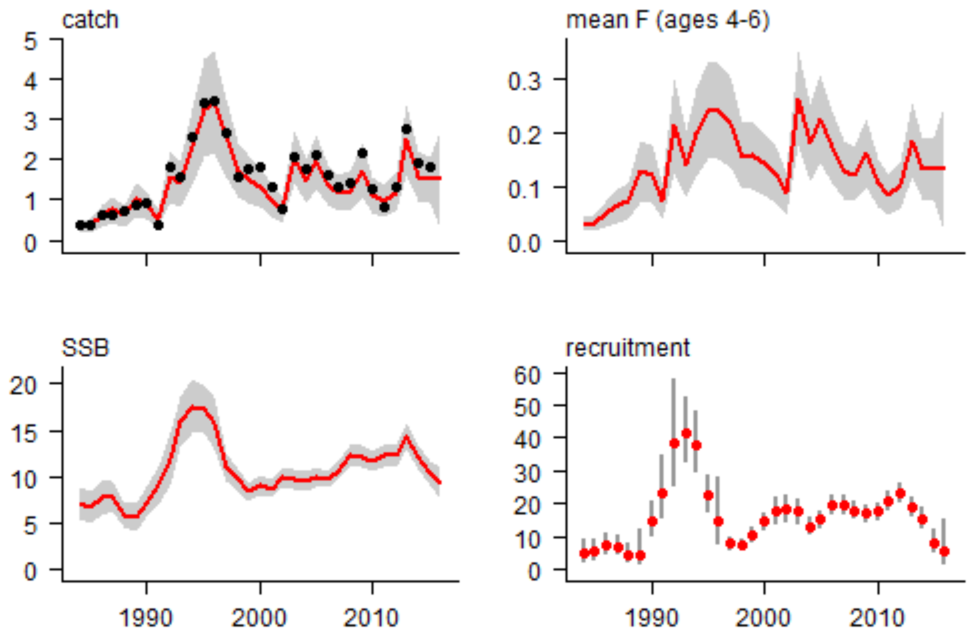

Figure 3.5.6: North East. TSA stock summaries from the final run. Catch and SSB are in terms of live weight (thousand tonnes) and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals.

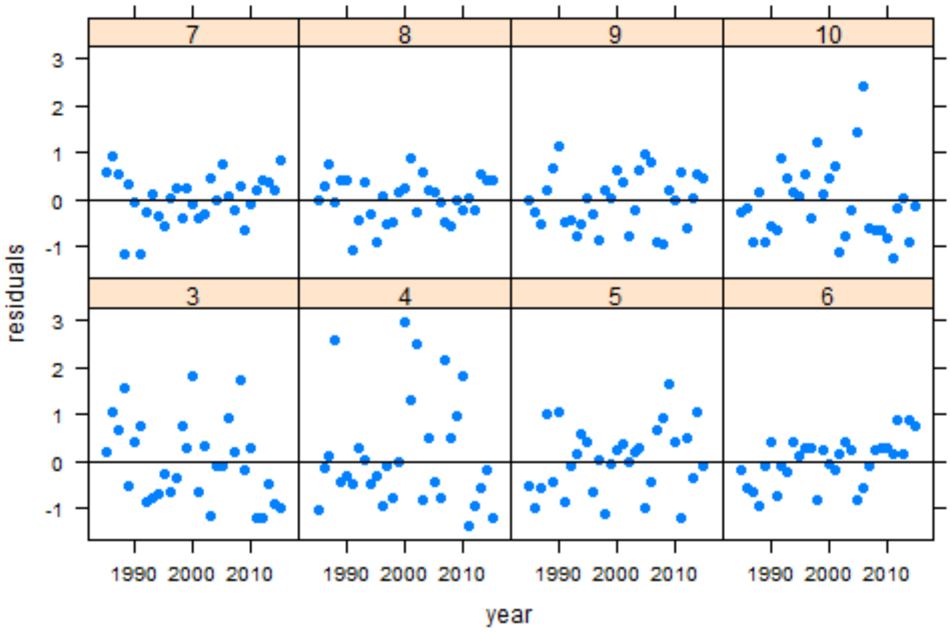

Figure 3.5.7: North East. Standardised catch residuals by age from the final TSA run.

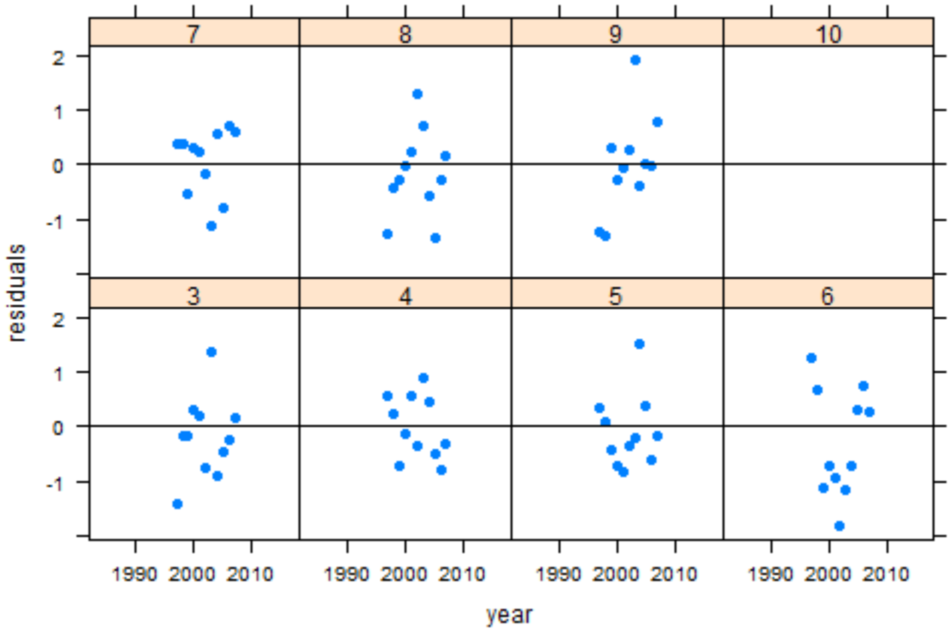

Figure 3.5.8: North East. Standardised survey residuals by age (Clupea survey) from the final TSA run.

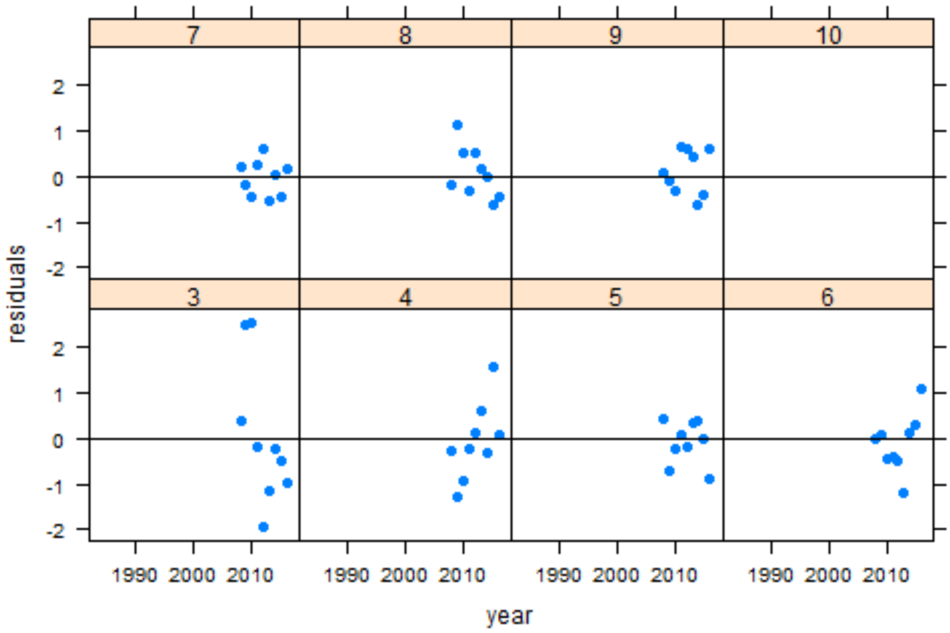

Figure 3.5.9: North East. Standardised survey residuals by age (Alba survey) from the final TSA run.

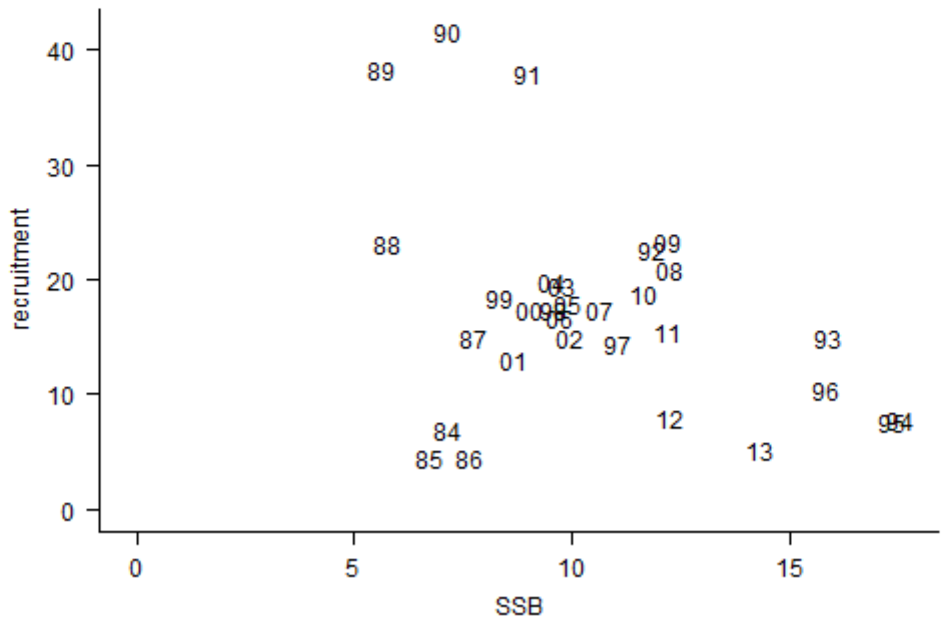

Figure 3.5.10: North East. Stock-recruit plot from the final TSA run. Recruitment is in millions (age 3) and SSB in thousand tonnes. Values are labelled with year class.

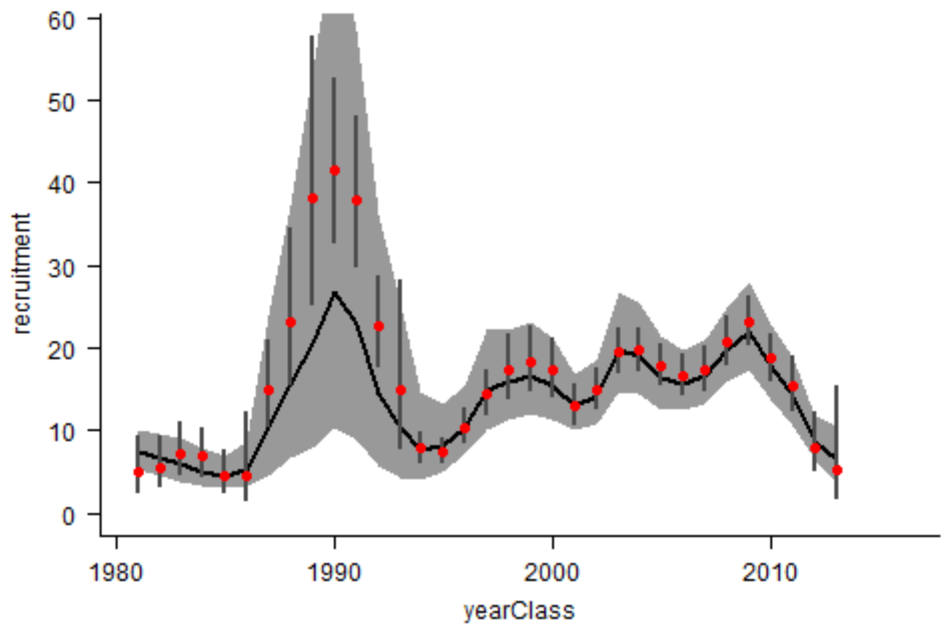

Figure 3.5.11: North East. Estimated recruitment time-series from the final TSA assessment. Red points give estimated values with grey bars indicating approximate pointwise 95% confidence intervals. The black line (also with 95% CI) shows the underlying random-walk recruitment model estimated by TSA.

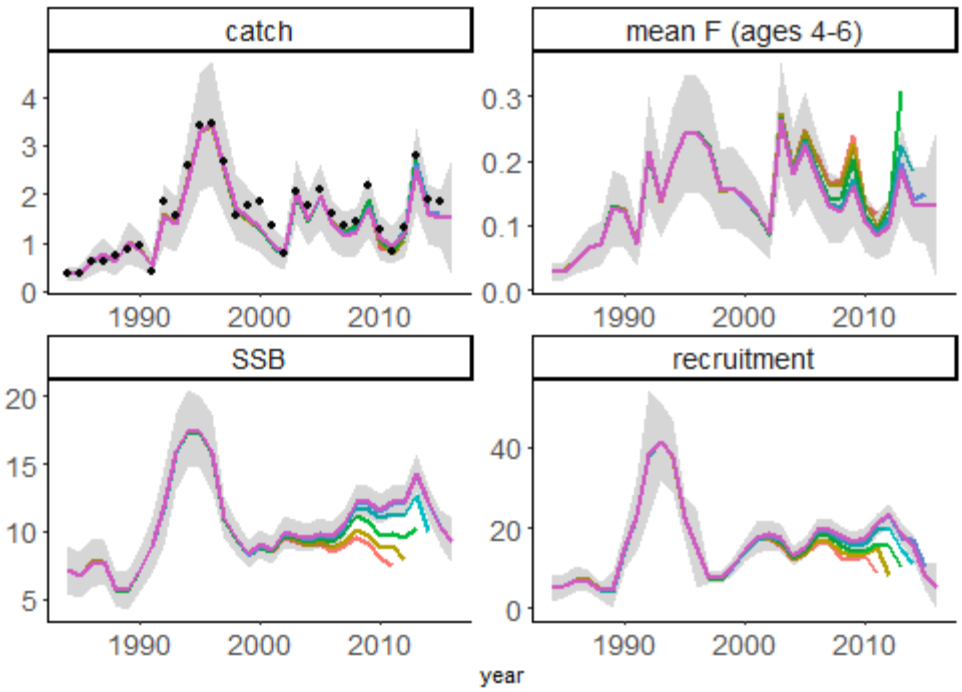

Figure 3.5.12: North East. Estimates of Catch, Mean $F_{4\text{-}6}$, SSB and Recruitment with final run 95% confidence intervals (grey shading) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment in millions.

Figure 3.5.13: North East. Comparison of final assessment results with previous assessment conducted in 2011. Recruitment is in thousands. SSB is shown as mean standardised (over the common time period) to allow for comparison between results in live weight (current assessment) and muscle weight (2011 assessment).

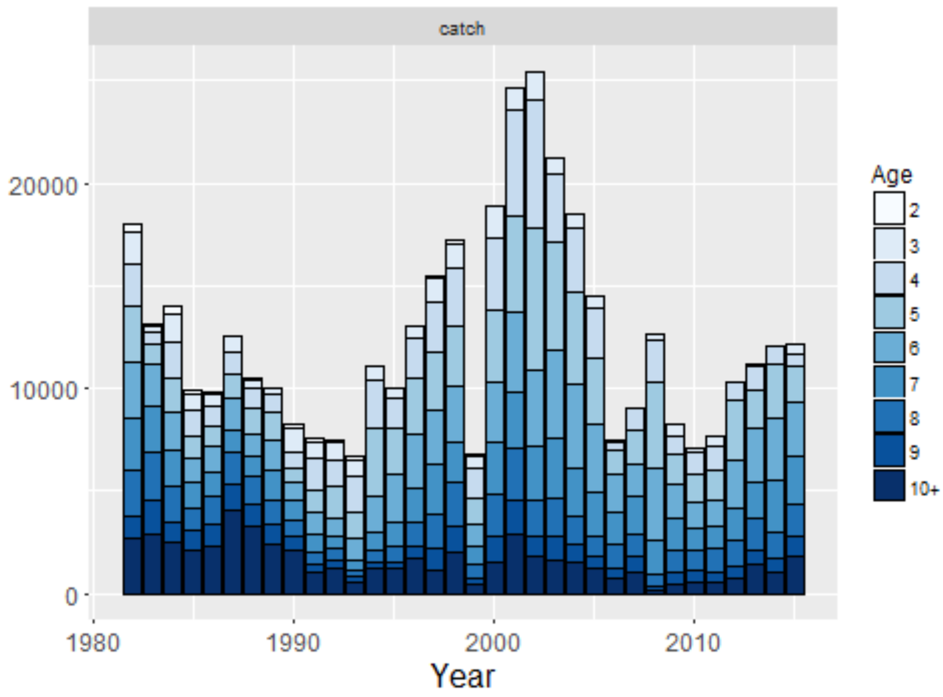

Figure 3.6.1: North West. Total catch-at-age numbers (in thousands).

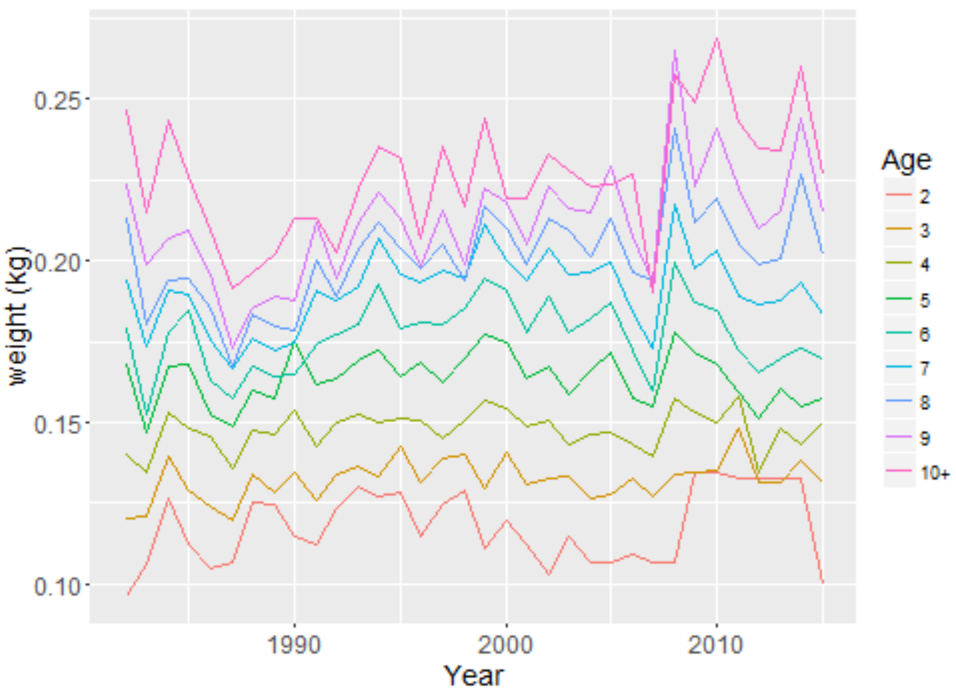

Figure 3.6.2: North West. Mean weights-at-age (kg) in total catch (also used for stock weights).

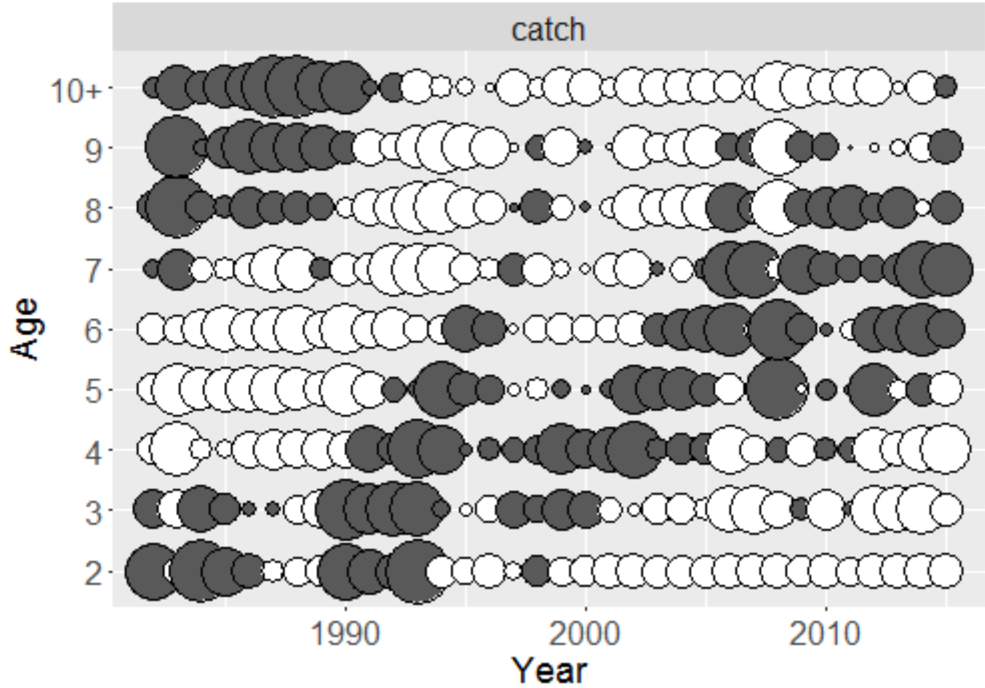

Figure 3.6.3: North West. Catch at age (by proportion): mean standardised over time by age class. Dark shaded circles represent above average values and white circles below average.

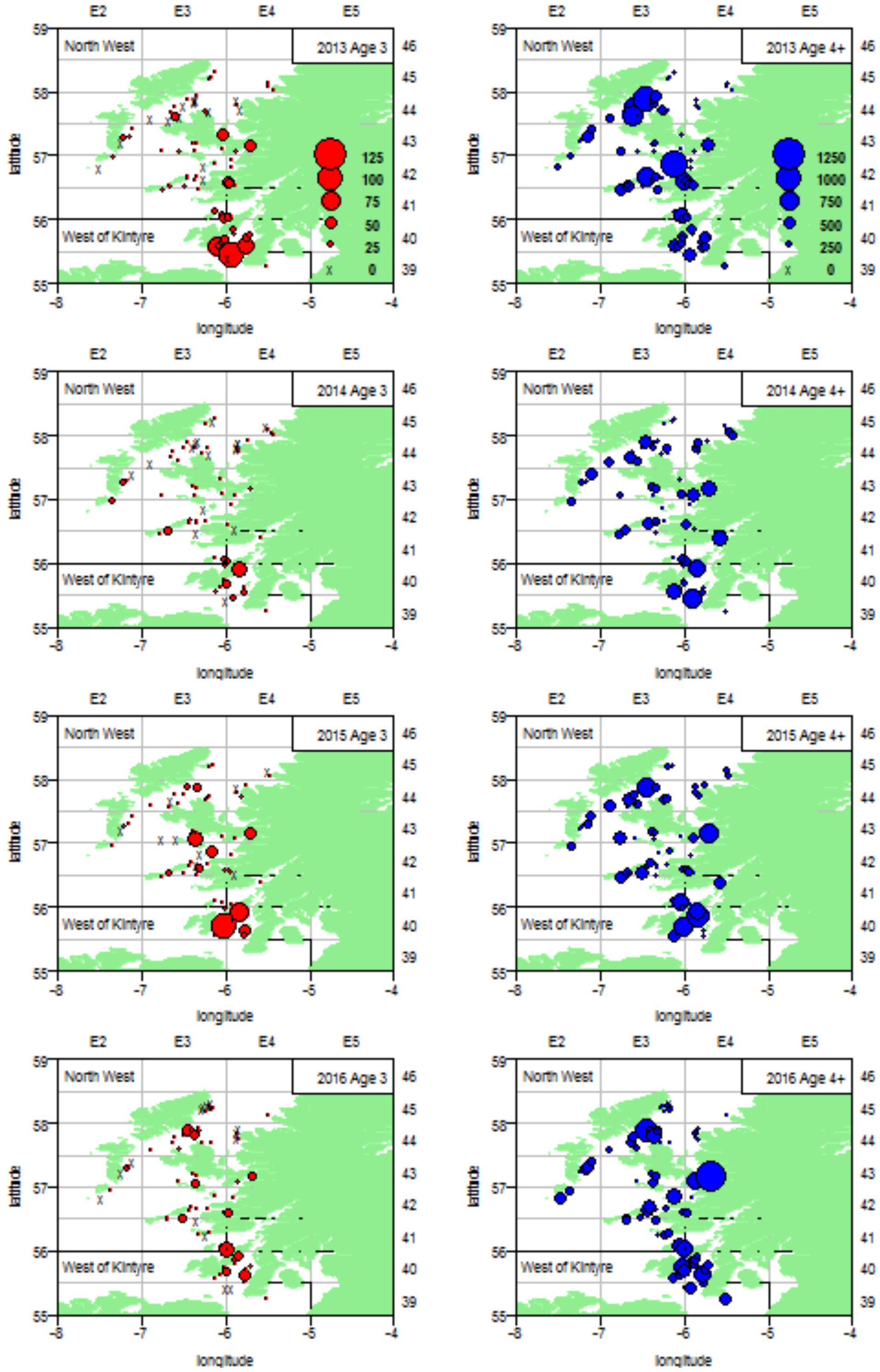

Figure 3.6.4: West coast survey. Distribution of dredge survey catch rates (2013-2016).

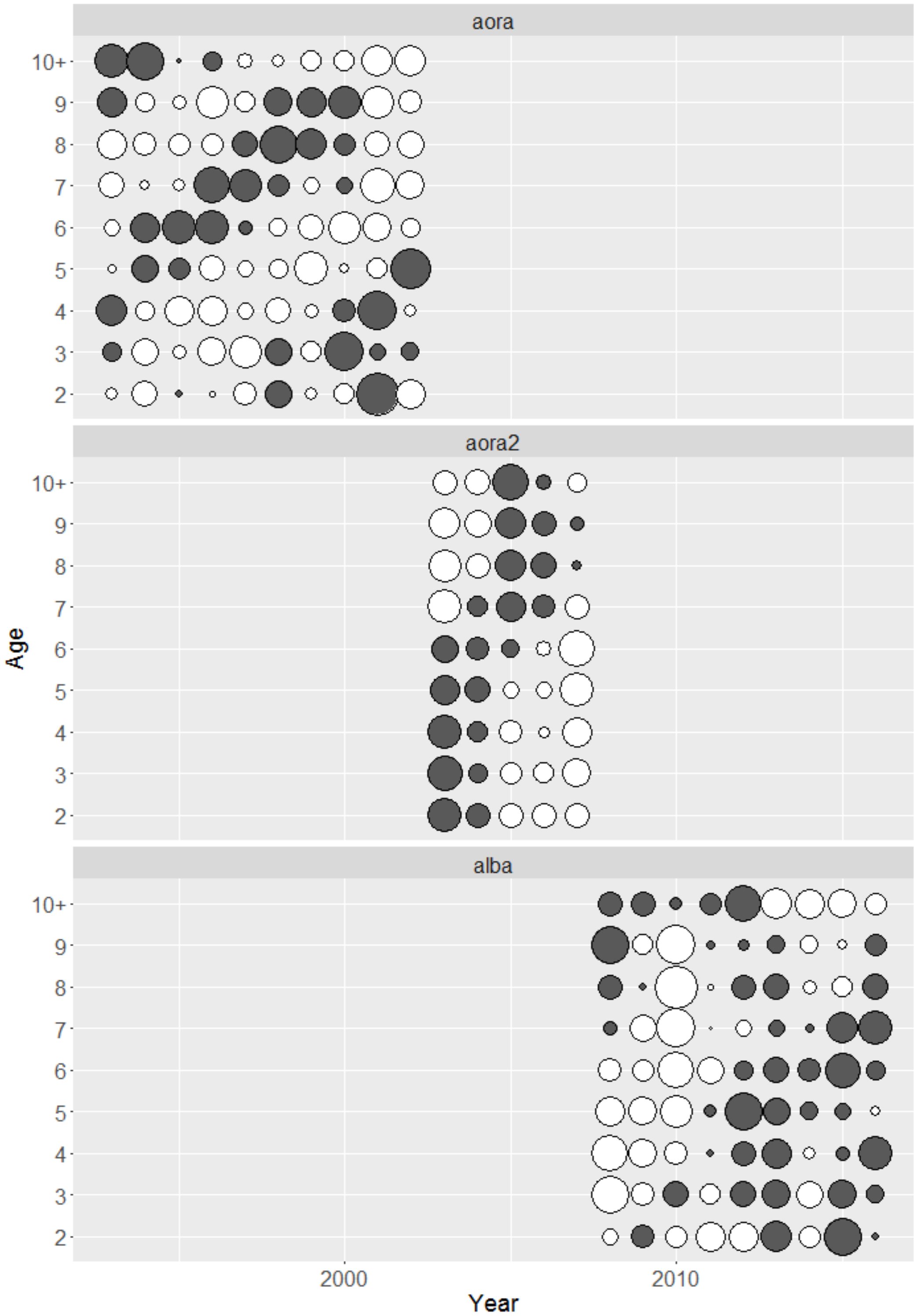

Figure 3.6.5: North West. Mean standardised survey catch at age. Dark shaded circles represent above average values and white circles below average.

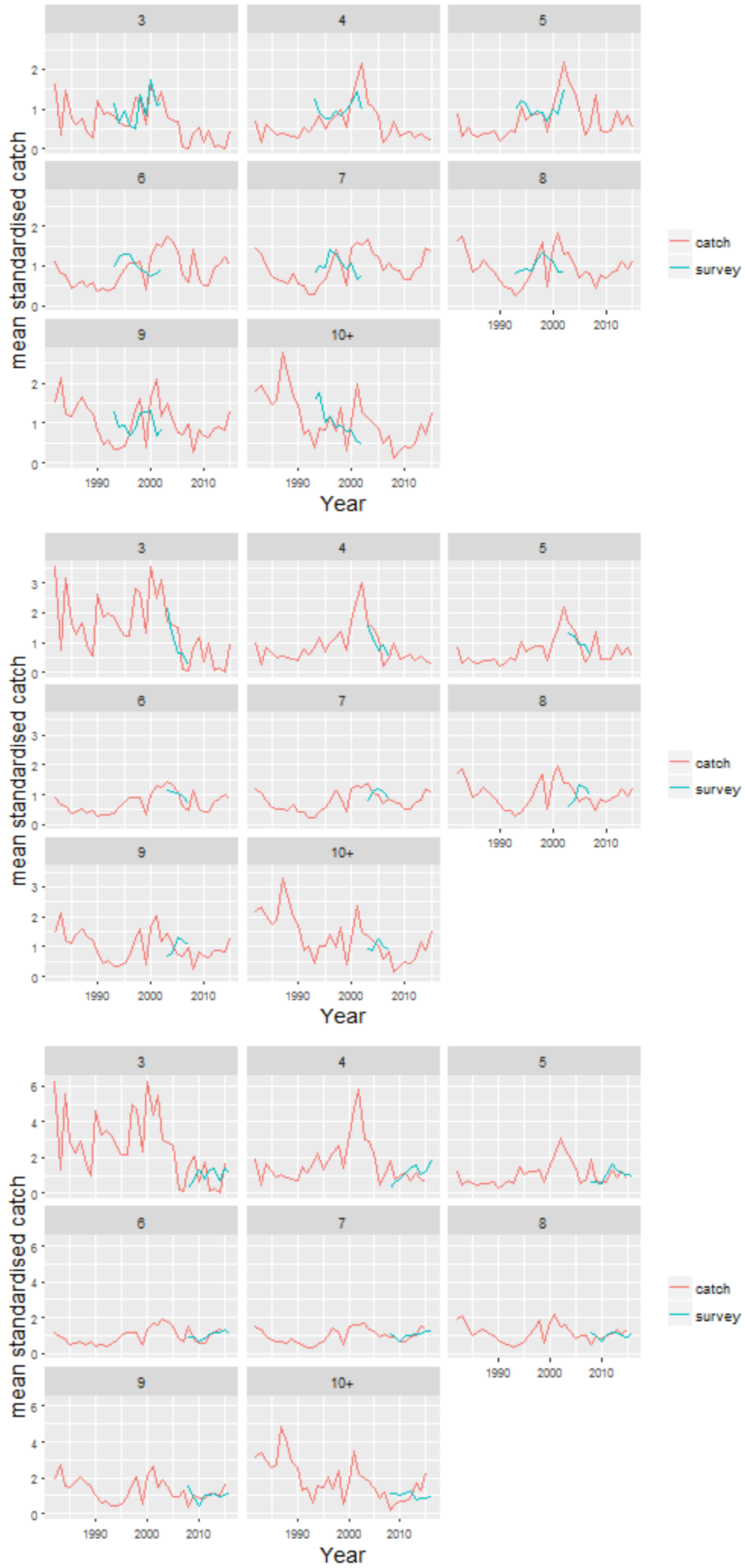

Figure 3.6.6: North West. Mean standardised survey and commercial catch at age comparison. Upper plot: Aora survey, middle plot: Aora II survey, lower plot: Alba survey.

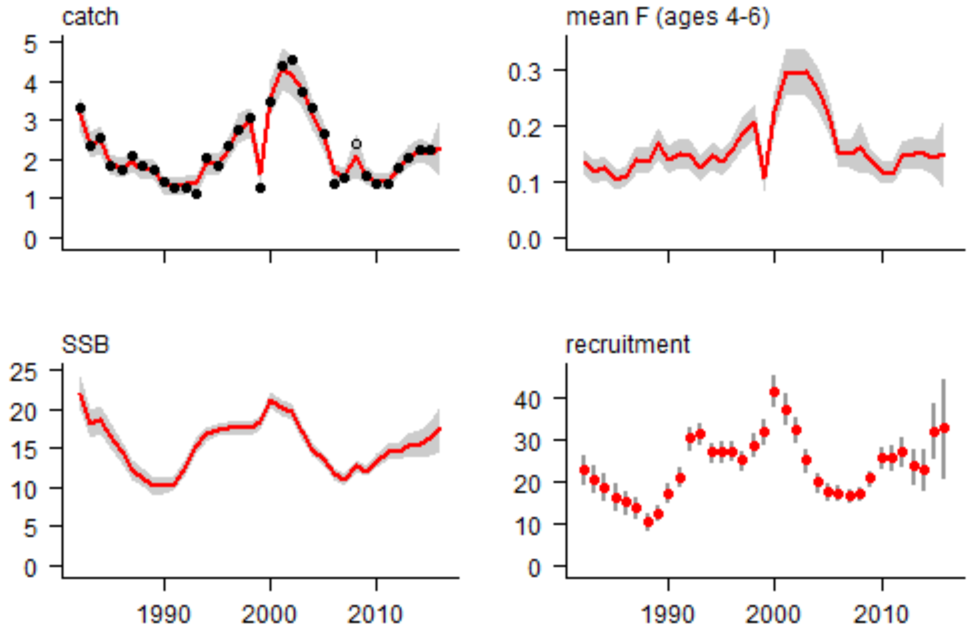

Figure 3.6.7: North West. TSA stock summaries from the final TSA run. Catch and SSB are in thousand tonnes and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals. Unfilled circle (catch data): data not included in the assessment.

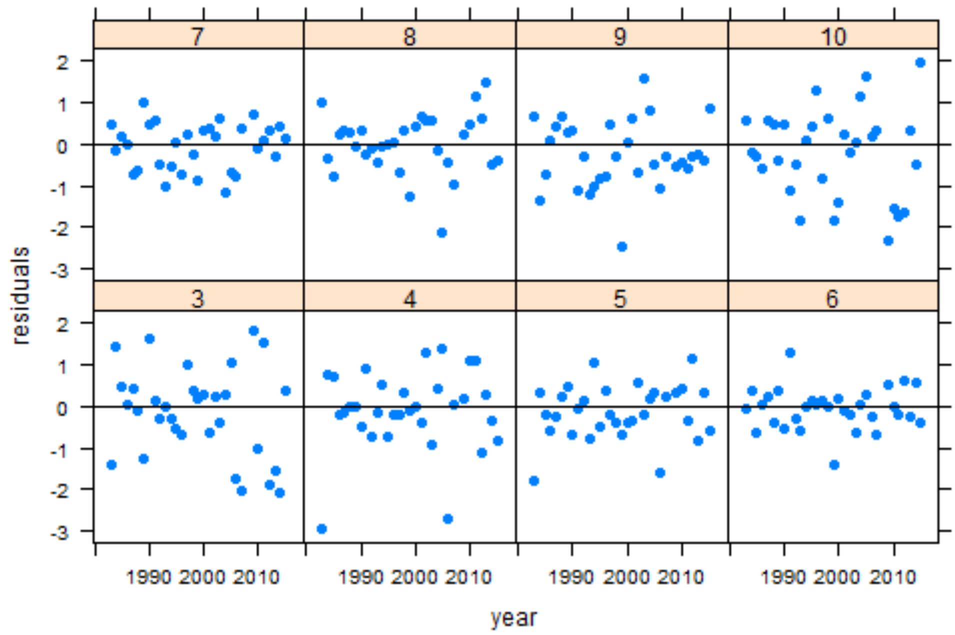

Figure 3.6.8: North West. Standardised catch residuals by age from the final TSA run.

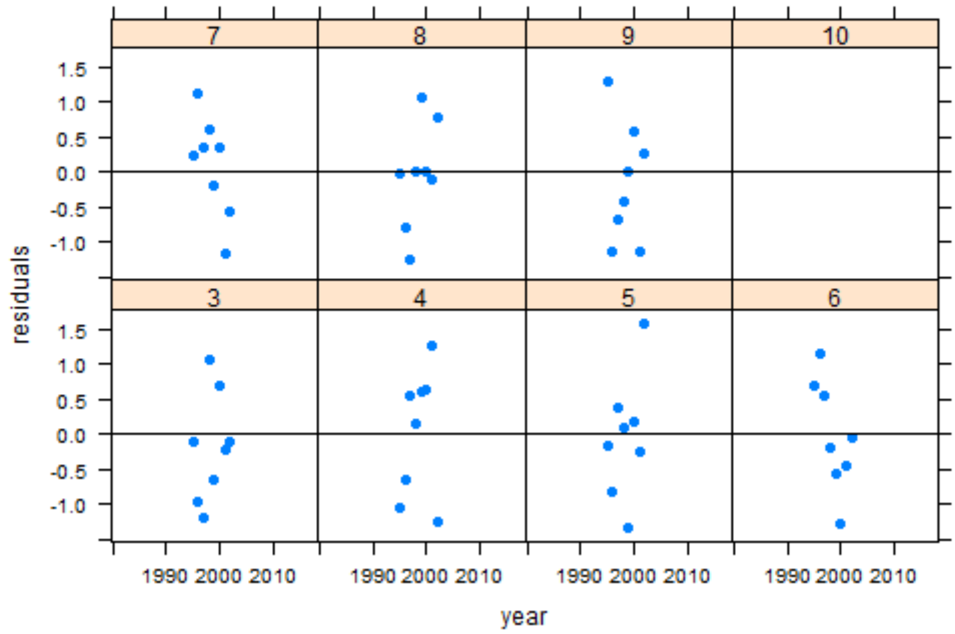

Figure 3.6.9: North West. Standardised survey residuals by age (Aora survey) from the final TSA run.

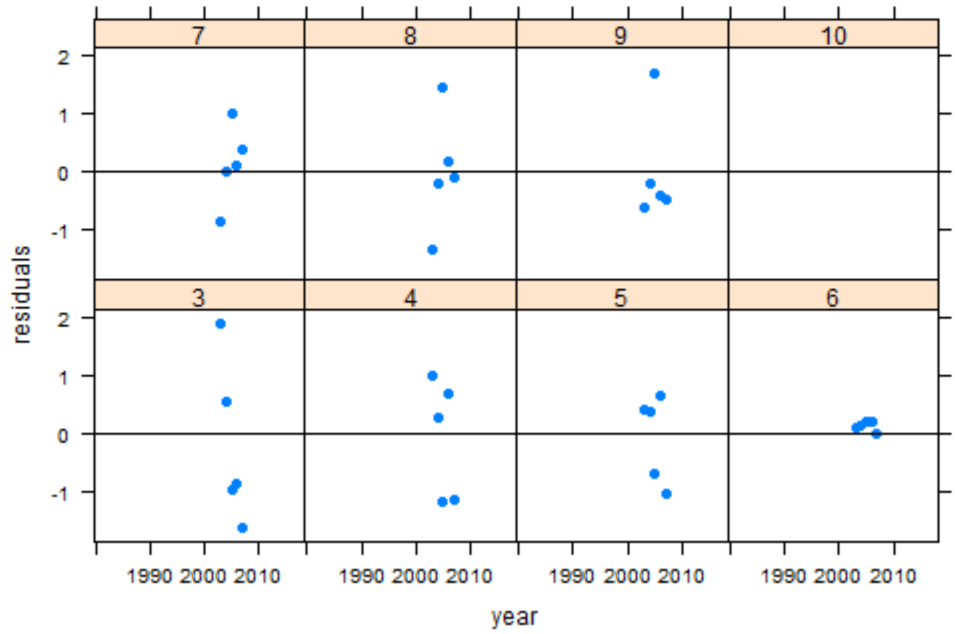

Figure 3.6.10: North West. Standardised survey residuals by age (Aora II survey) from the final TSA run.

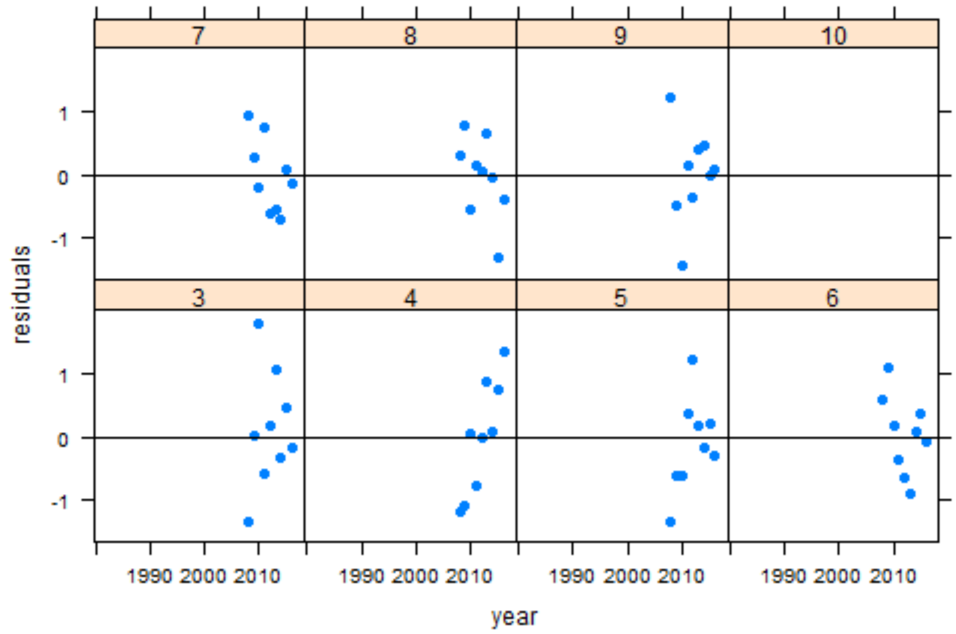

Figure 3.6.11: North West. Standardised survey residuals by age (Alba survey) from the final TSA run.

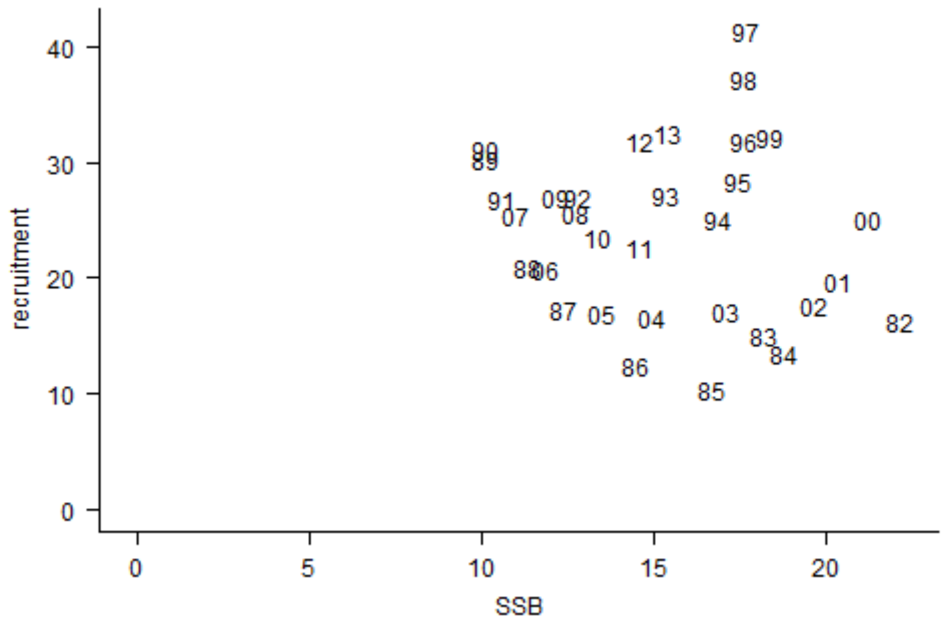

Figure 3.6.12: North West. Stock-recruit plot from the final TSA run. Recruitment (age 3) is in millions and SSB in thousand tonnes. Values are labelled with year class.

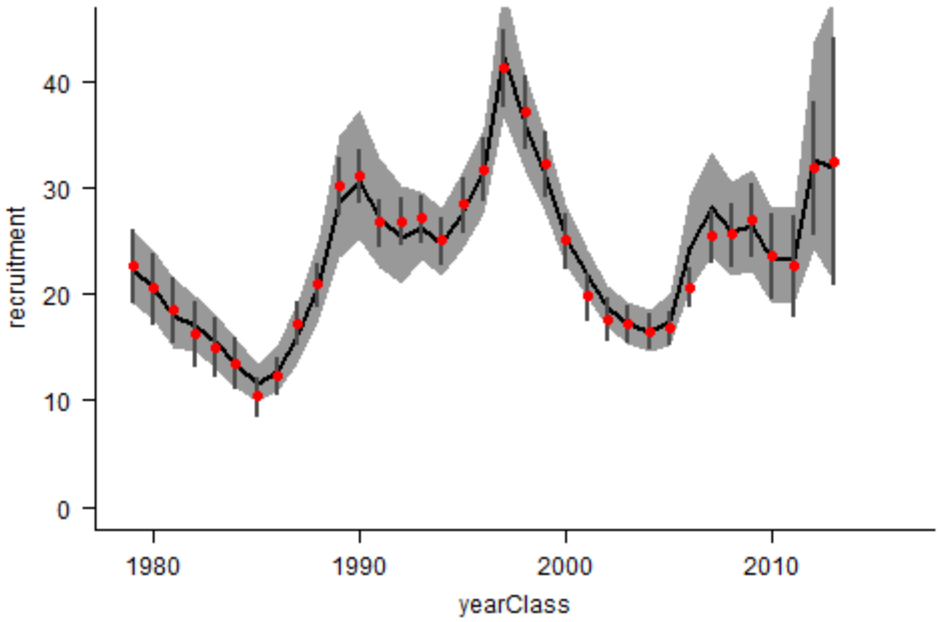

Figure 3.6.13: North West. Estimated recruitment time-series from the final TSA assessment. Red points give estimated values with grey bars indicating approximate pointwise 95% confidence intervals. The black line (also with 95% CI) shows the underlying random-walk recruitment model estimated by TSA.

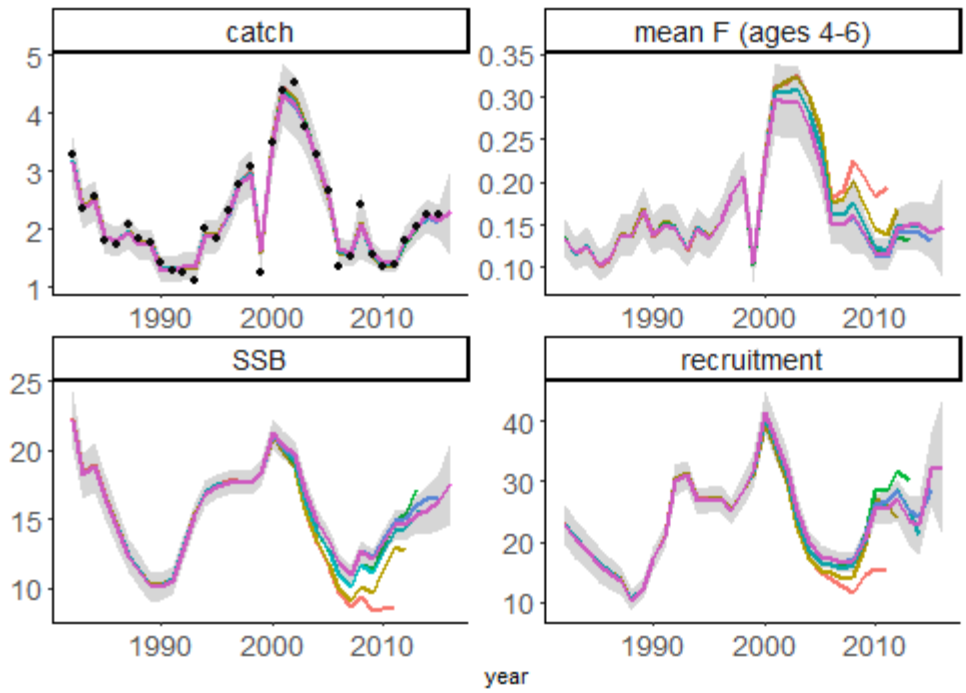

Figure 3.6.14: North West. Estimates of Catch, Mean F_{4-6}, SSB and Recruitment with final run 95% confidence intervals (grey shading) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment in millions.

Figure 3.6.15: North West. Comparison of final assessment results with previous assessment conducted in 2011. Recruitment is in thousands. SSB is shown as mean standardised (over the common time period) to allow for comparison between results in live weight (current assessment) and muscle weight (2011 assessment).

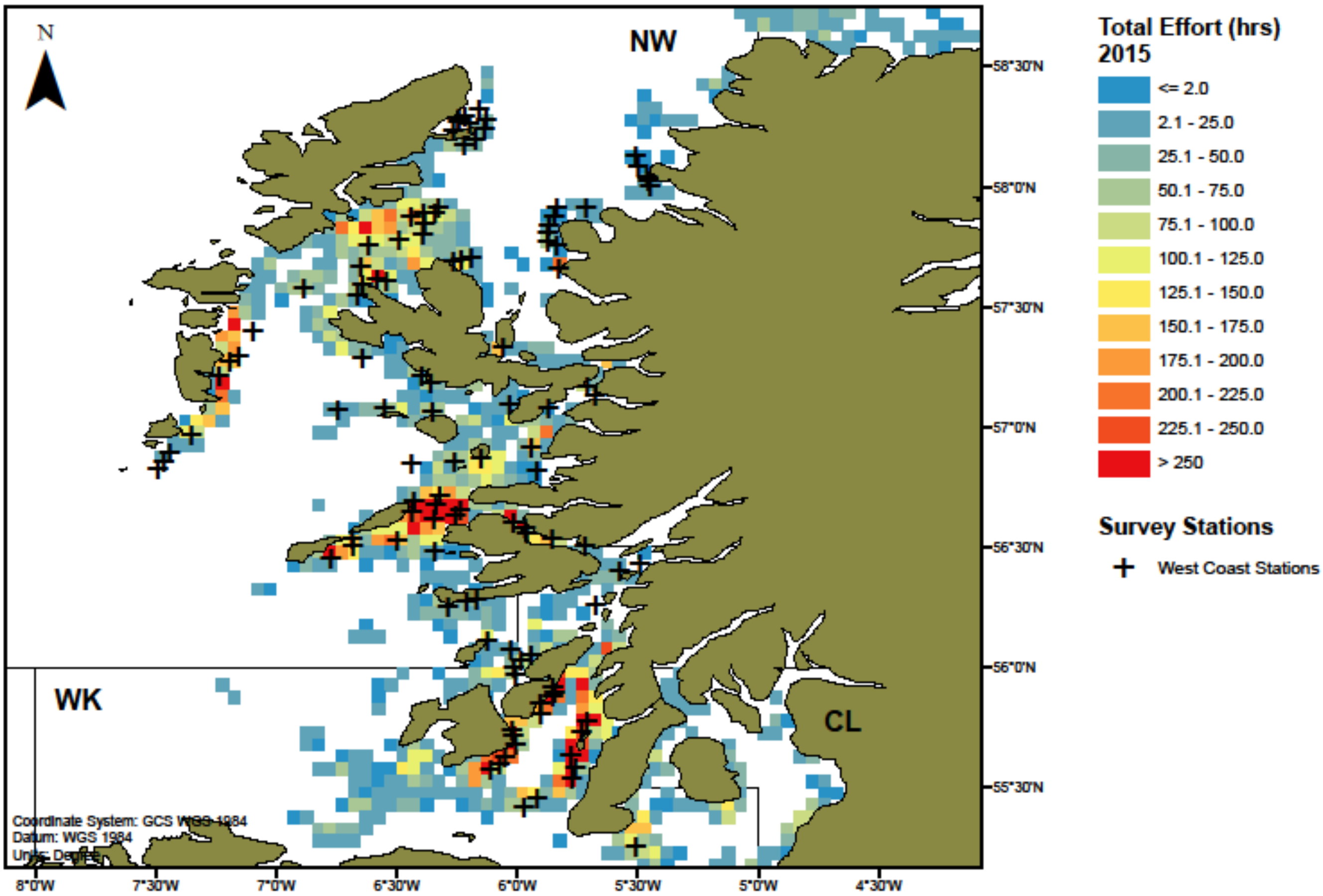

Figure 3.6.16: West coast survey. VMS effort intensity (UK vessels) overlaid with survey station locations (shown as crosses).

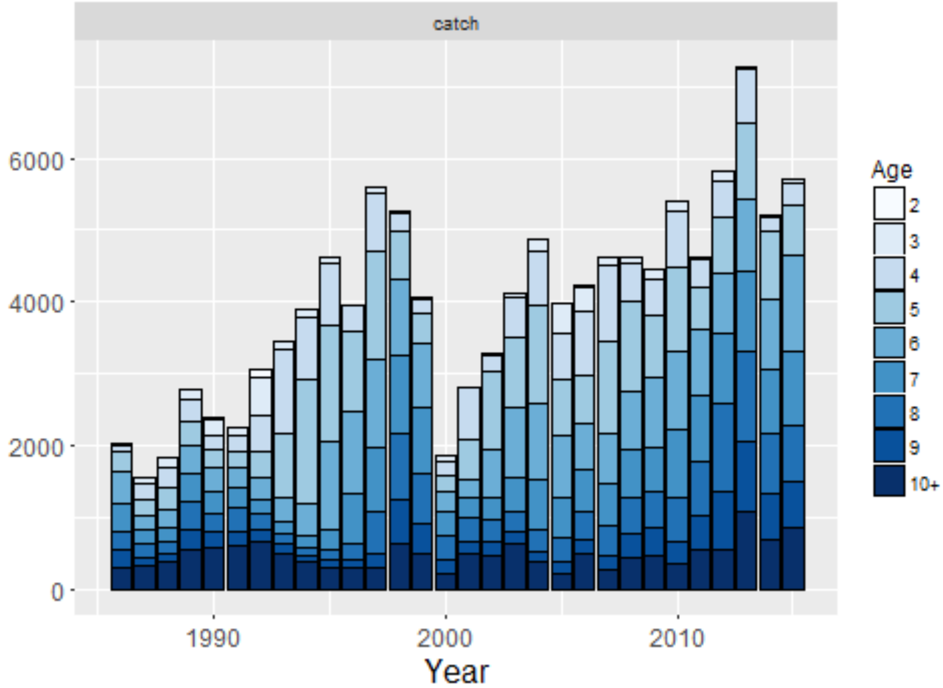

Figure 3.8.1: Shetland. Total catch-at-age numbers (in thousands).

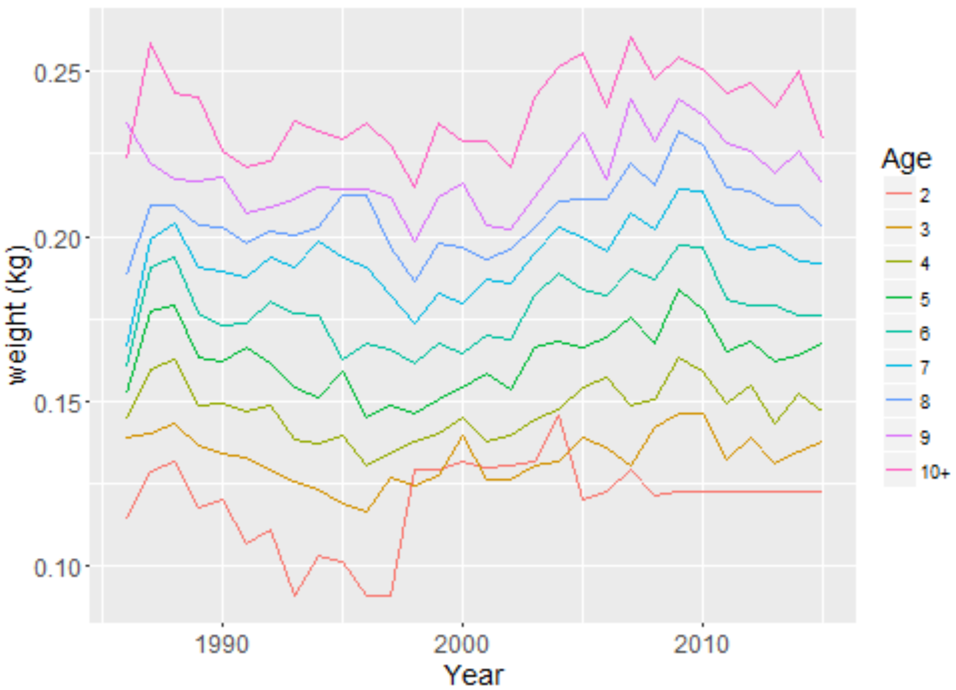

Figure 3.8.2: Shetland. Mean weights-at-age (kg) in total catch (also used for stock weights).

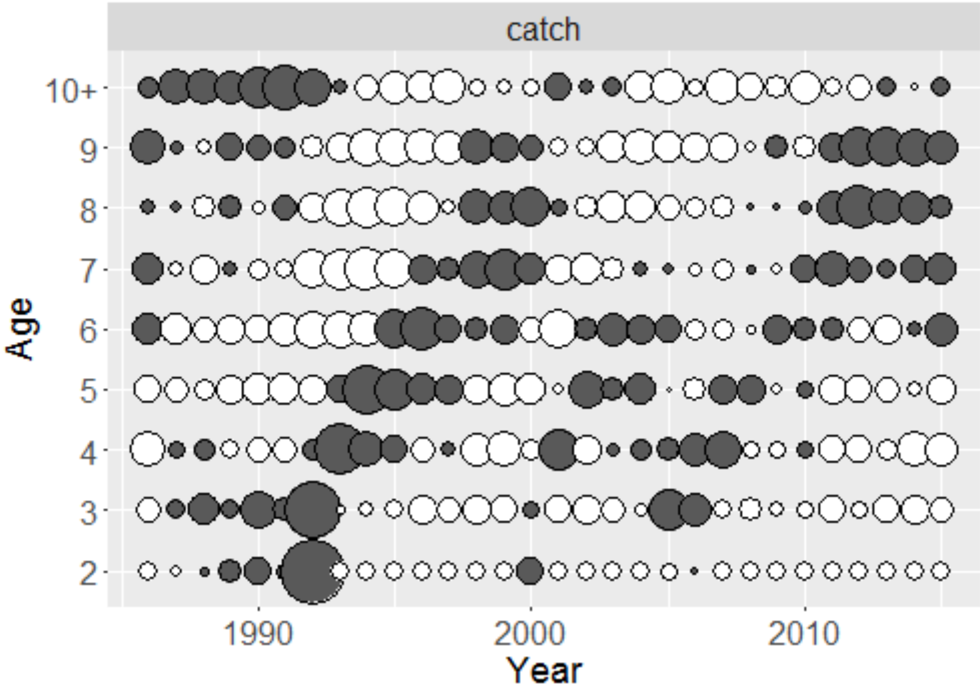

Figure 3.8.3: Shetland. Catch at age (by proportion): mean standardised over time by age class. Dark shaded circles represent above average values and white circles below average.

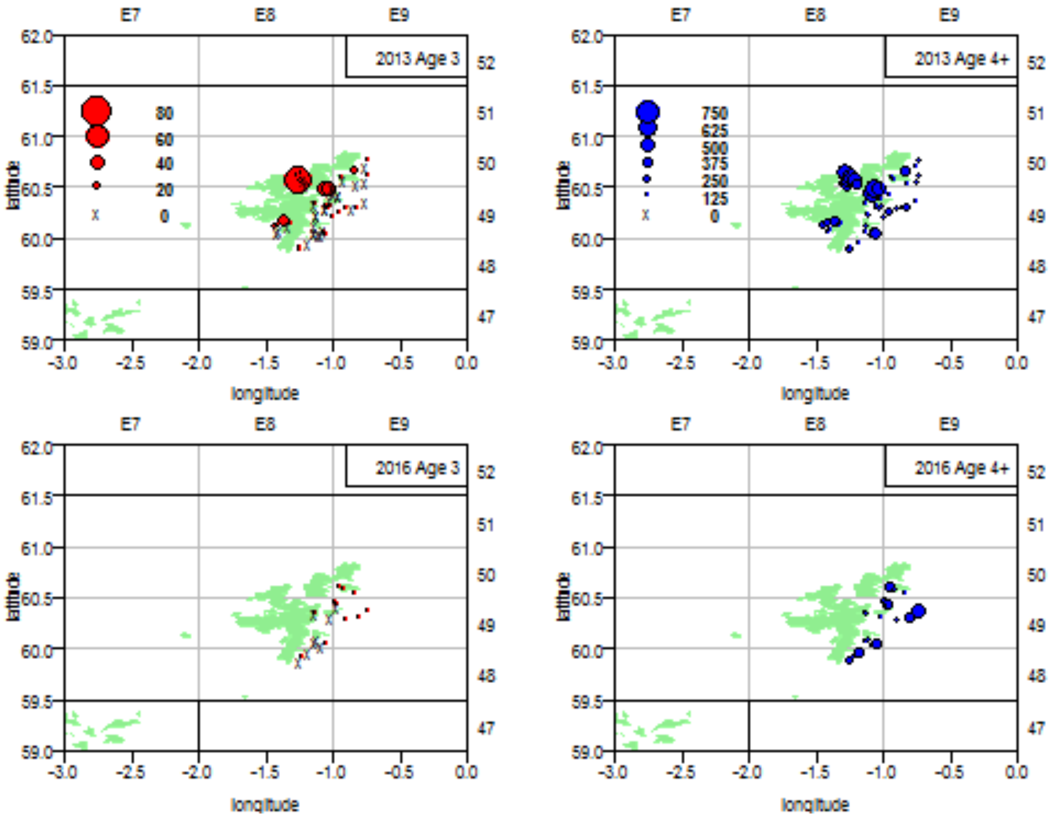

Figure 3.8.4: Shetland. Distribution of dredge survey catch rates (2013-2016). Note that due to poor weather, no surveys could be conducted in 2014 and 2015 and only a partial survey took place in 2016.

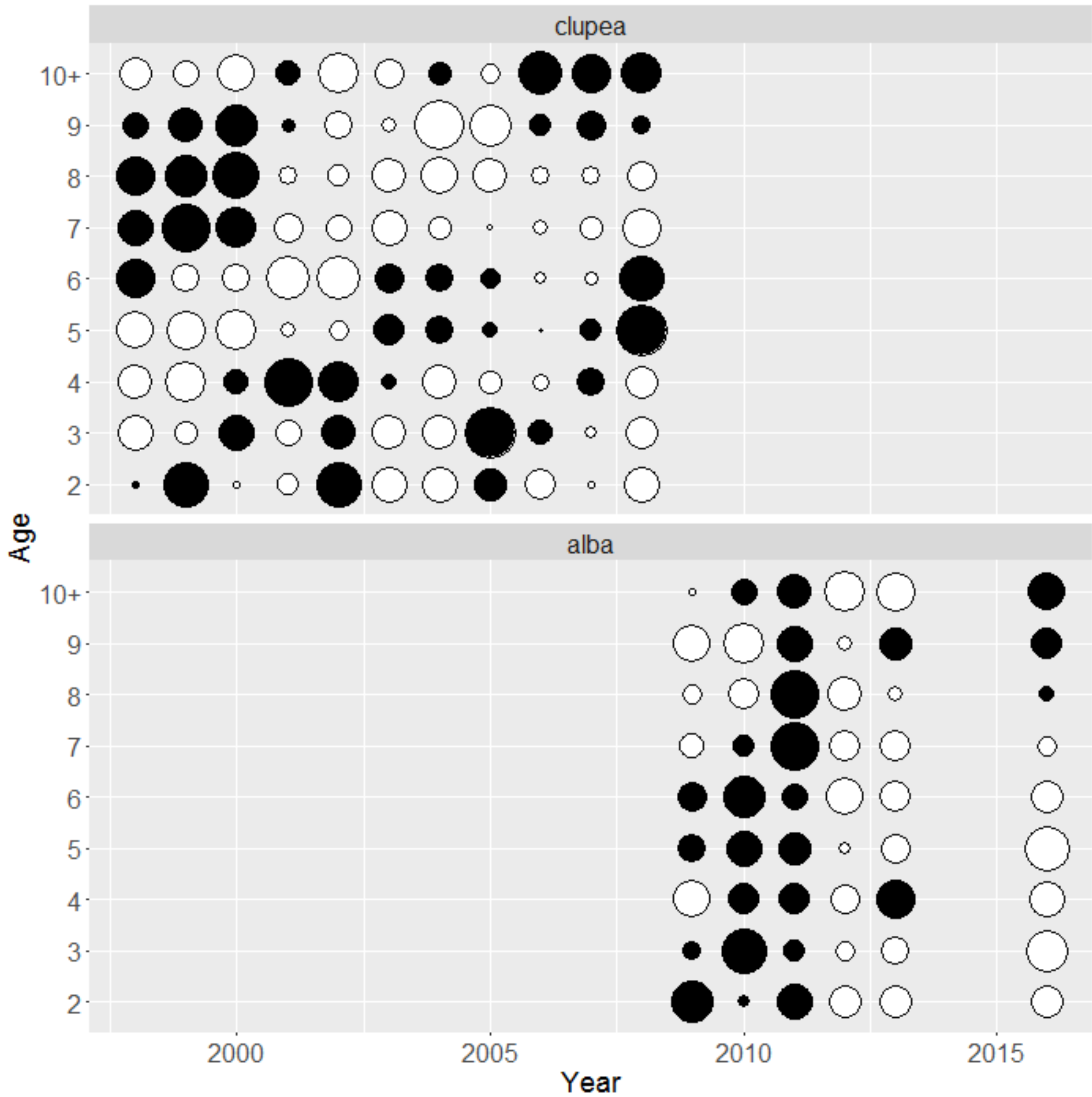

Figure 3.8.5: Shetland. Mean standardised survey catch at age. Dark shaded circles represent above average values and white circles below average.

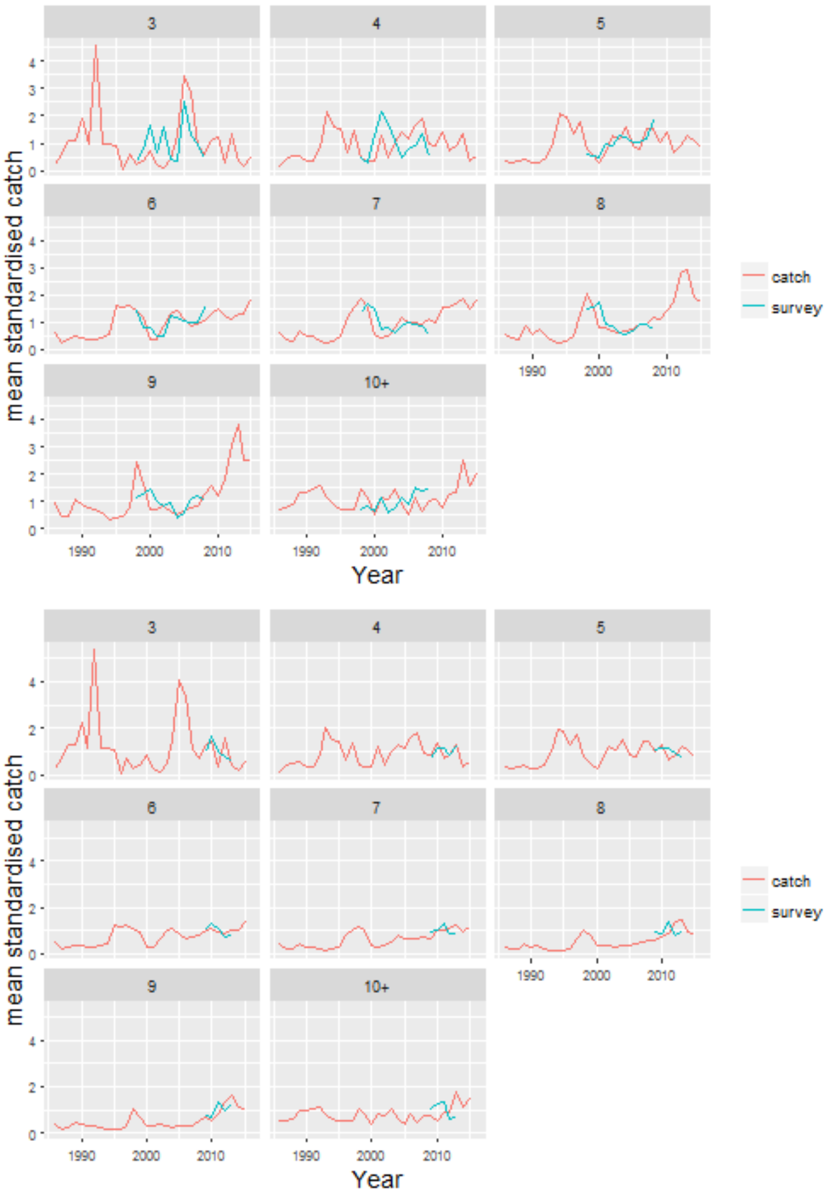

Figure 3.8.6: Shetland. Mean standardised survey and commercial catch at age comparison. Upper plot: Clupea survey, lower plot: Alba survey.

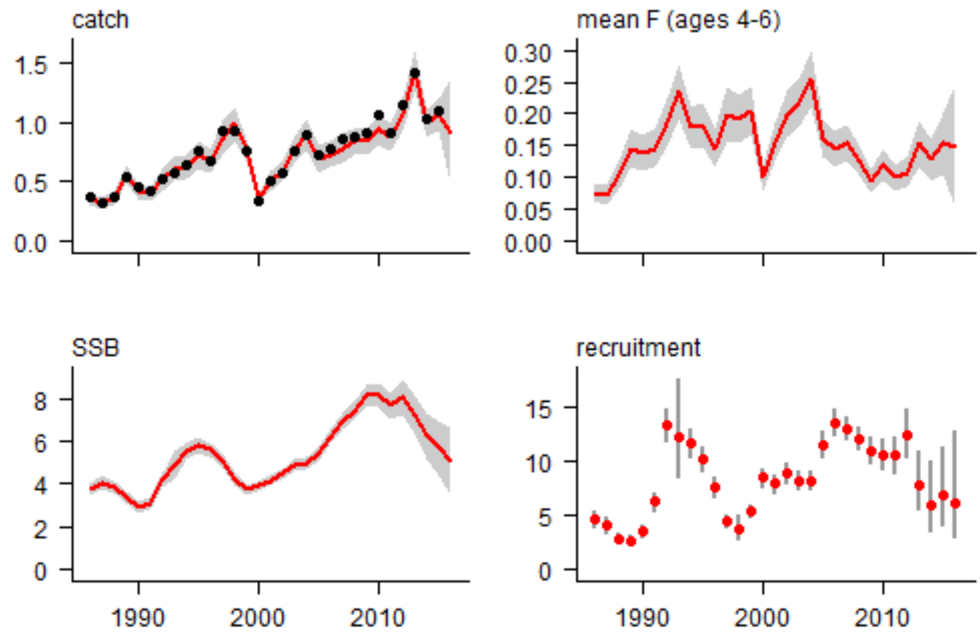

Figure 3.8.7: Shetland. TSA stock summaries from the final TSA run. Catch and SSB are in thousand tonnes and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals.

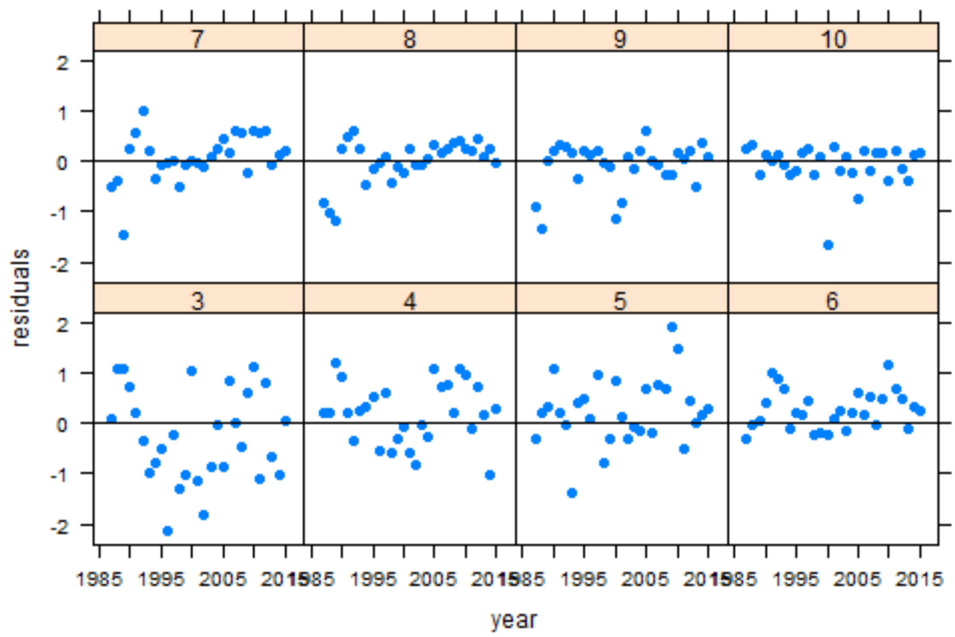

Figure 3.8.8: Shetland. Standardised catch residuals by age from the final TSA run.

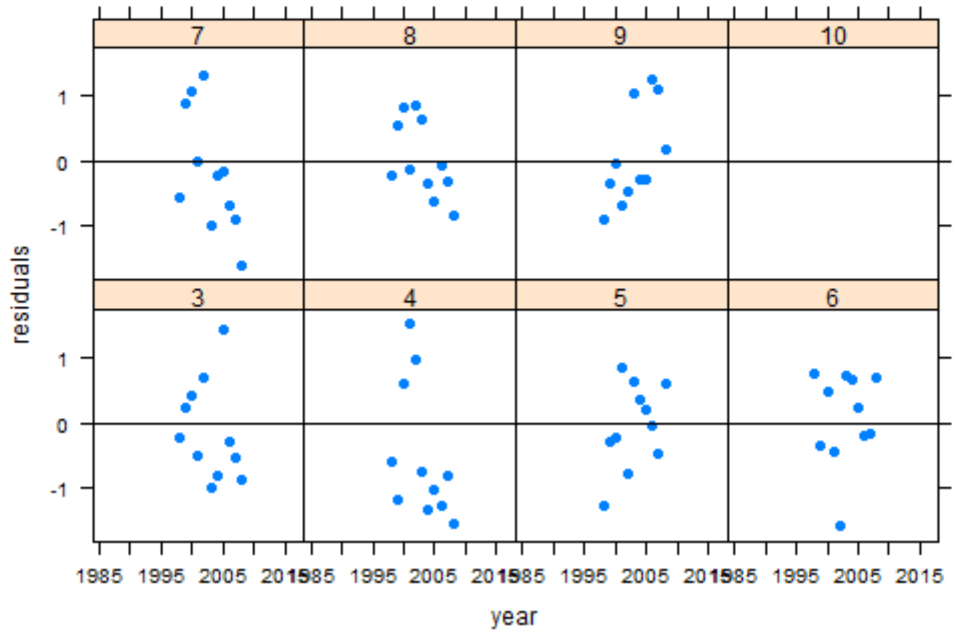

Figure 3.8.9: Shetland. Standardised survey residuals by age (Clupea survey) from the final TSA run.

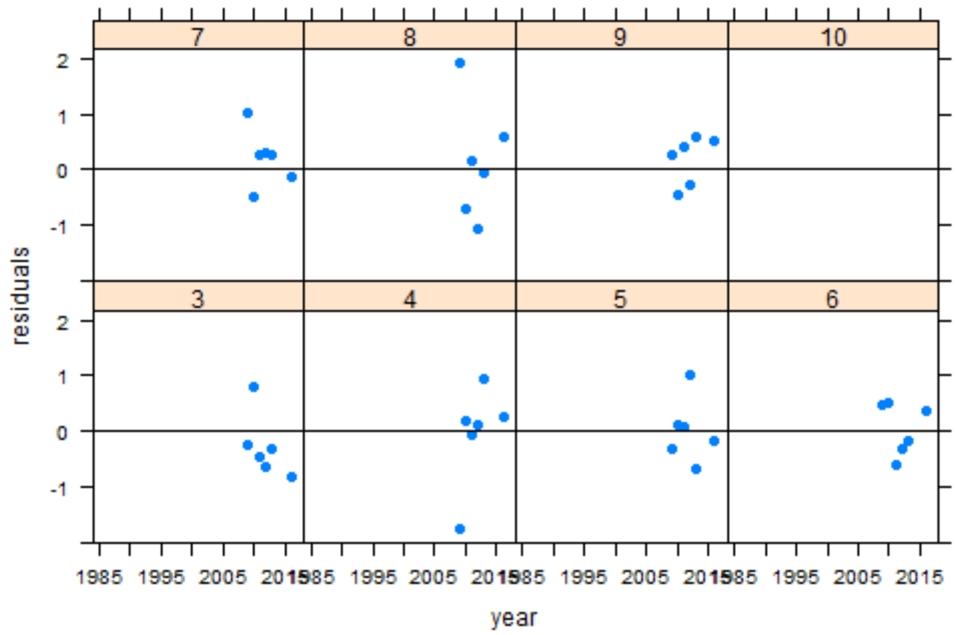

Figure 3.8.10: Shetland. Standardised survey residuals by age (Alba survey) from the final TSA run.

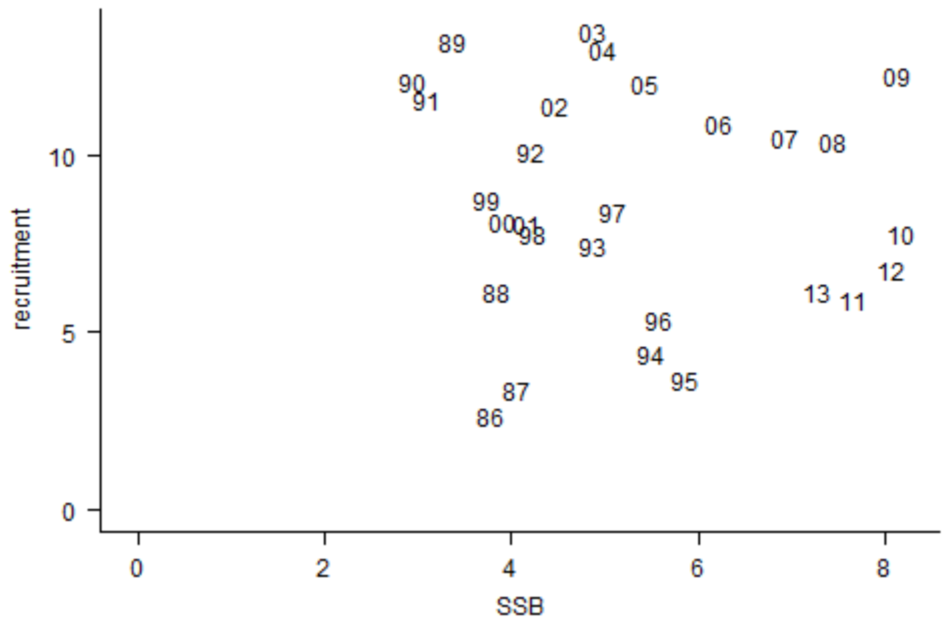

Figure 3.8.11: Shetland. Stock-recruit plot from the final TSA run. Recruitment (age 3) is in millions and SSB in thousand tonnes. Values are labelled with year class.

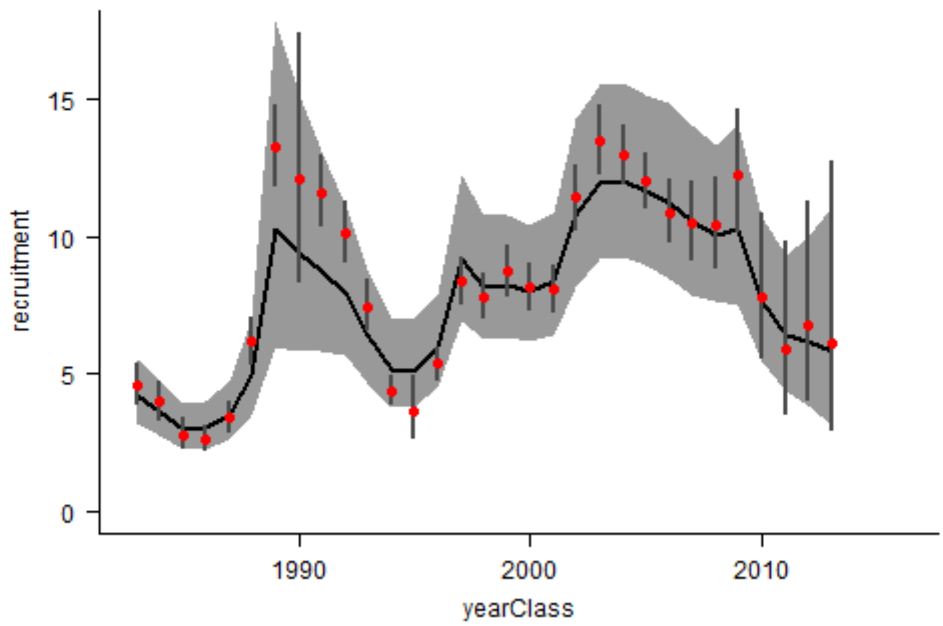

Figure 3.8.12: Shetland. Estimated recruitment time-series from the final TSA assessment. Red points give estimated values with grey bars indicating approximate pointwise 95% confidence intervals. The black line (also with 95% CI) shows the underlying random-walk recruitment model estimated by TSA.

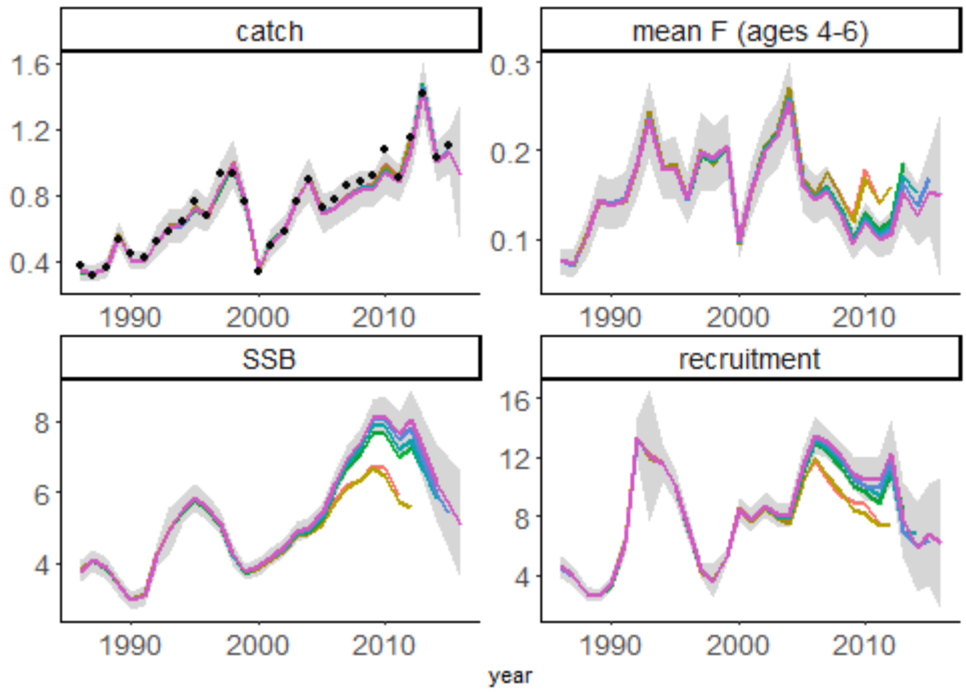

Figure 3.8.13: Shetland. Estimates of Catch, Mean $F_{4\text{-}6}$, SSB and Recruitment with final run 95% confidence intervals (grey shading) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment (age 3) in millions.

Figure 3.8.14: Shetland. Comparison of final assessment results with previous assessment conducted in 2011. Recruitment is in thousands. SSB is shown as mean standardised (over the common time period) to allow for comparison between results in live weight (current assessment) and muscle weight (2011 assessment).

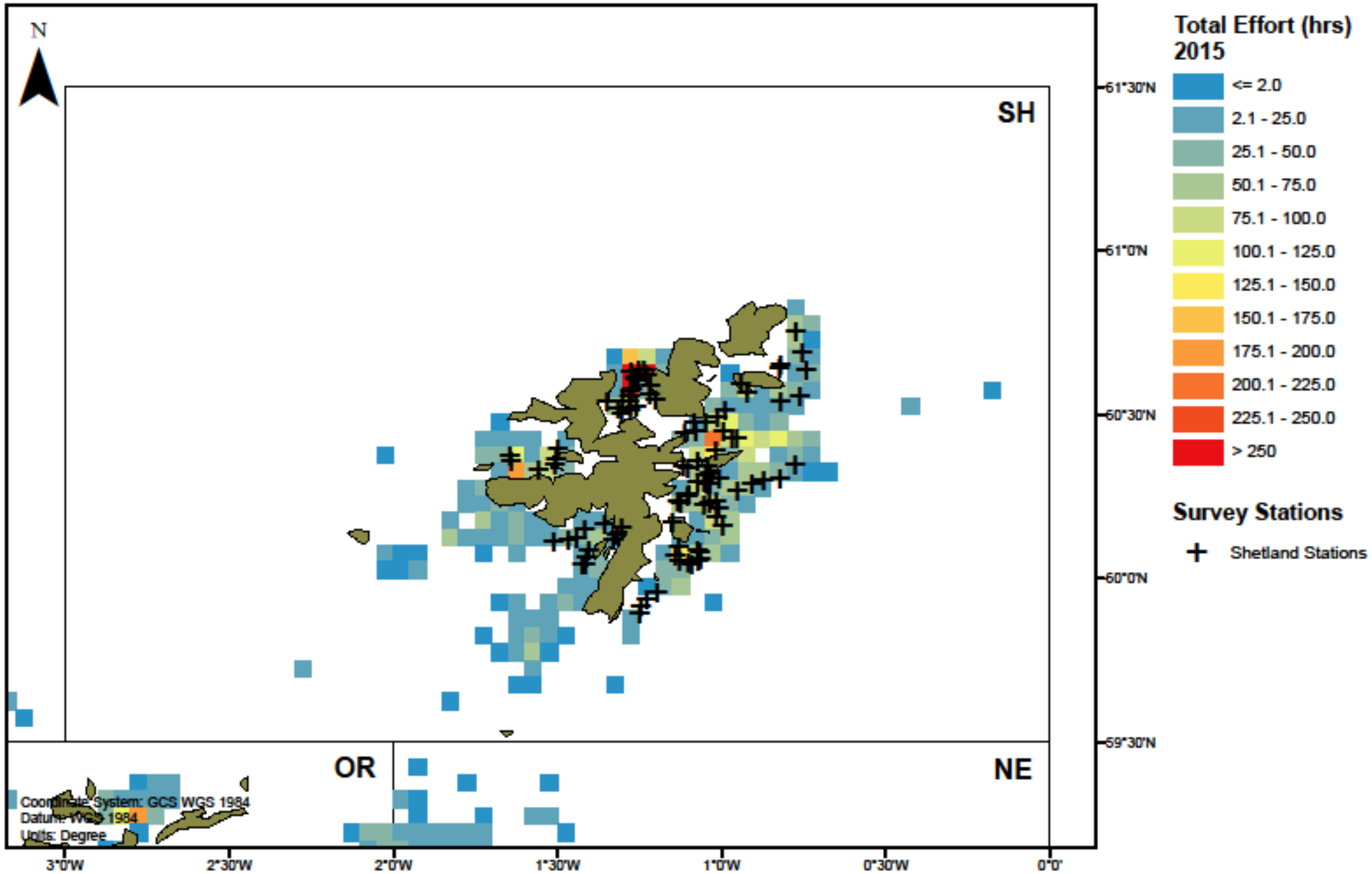

Figure 3.8.15: Shetland survey. VMS effort intensity (UK vessels) overlaid with survey station locations (shown as crosses).

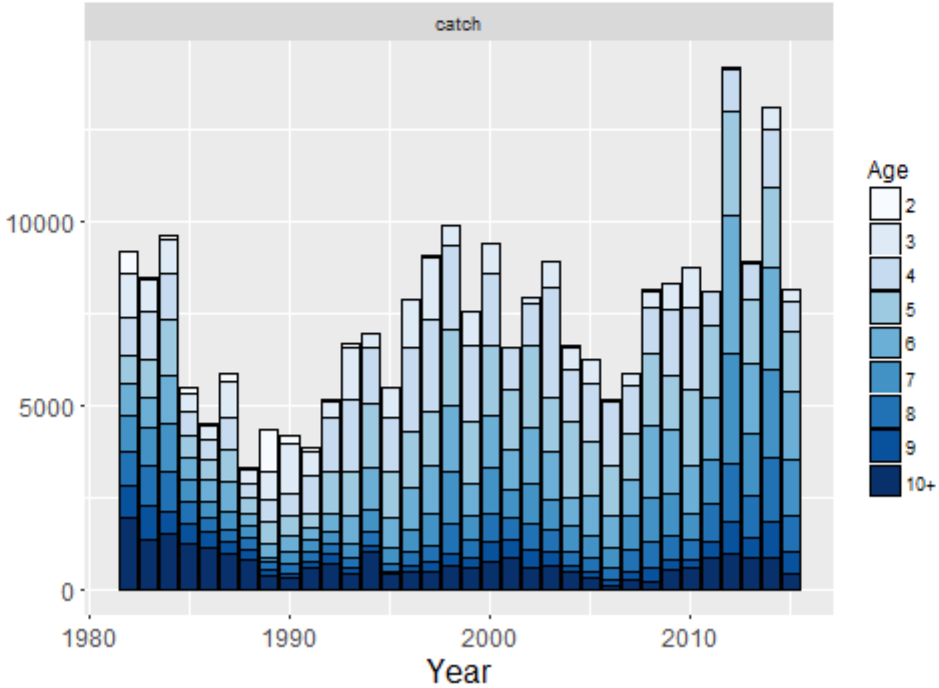

Figure 3.9.1: West of Kintyre. Total catch-at-age numbers (in thousands).

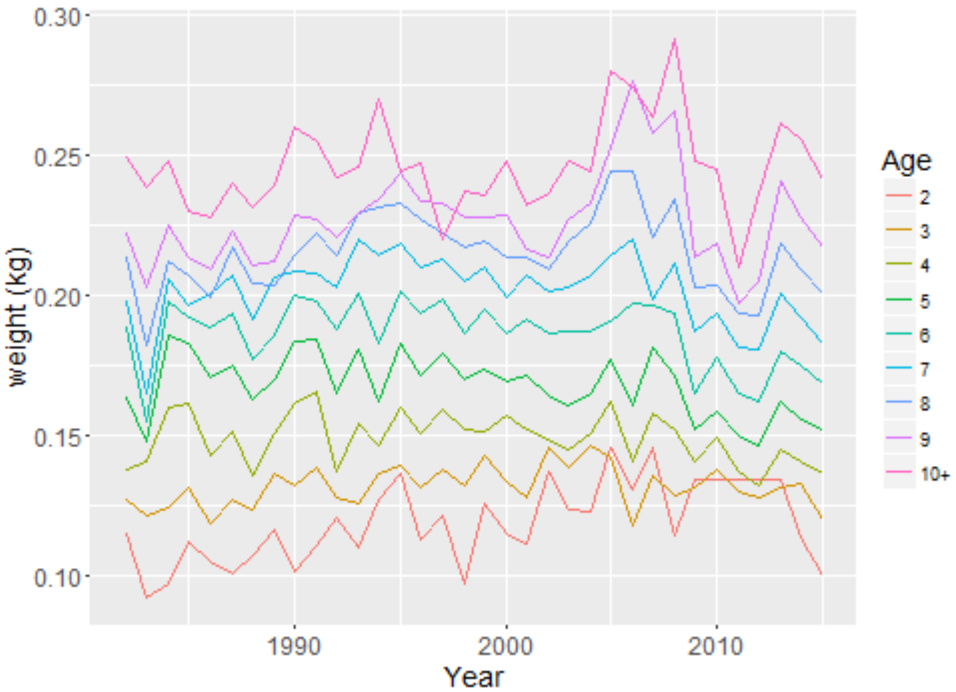

Figure 3.9.2: West of Kintyre. Mean weights-at-age (kg) in total catch (also used for stock weights).

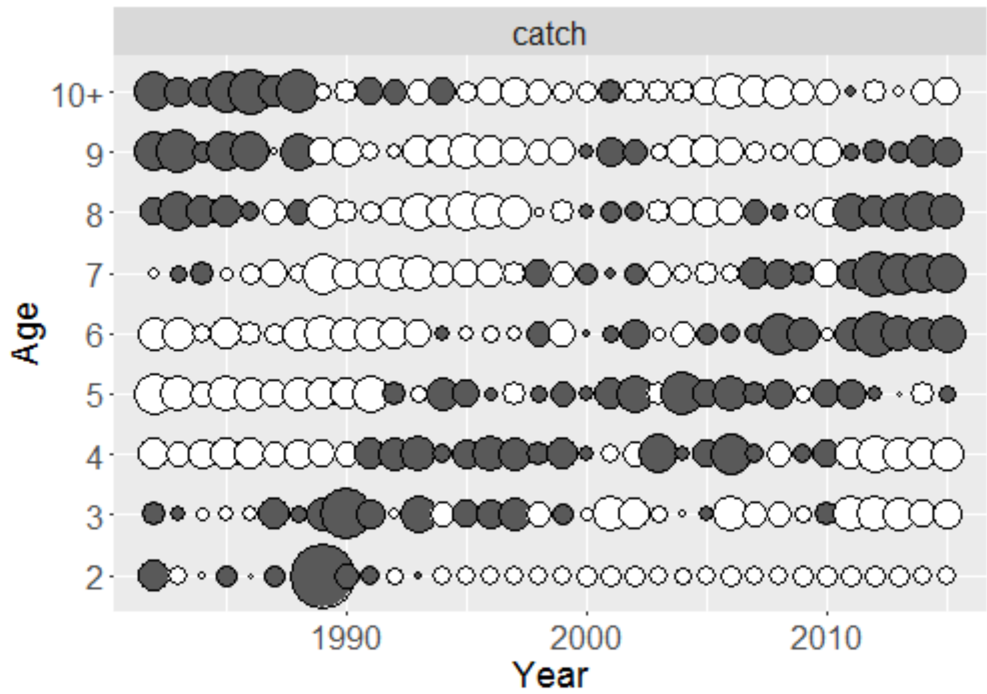

Figure 3.9.3: West of Kintyre. Catch at age (by proportion): mean standardised over time by age class. Dark shaded circles represent above average values and white circles below average.

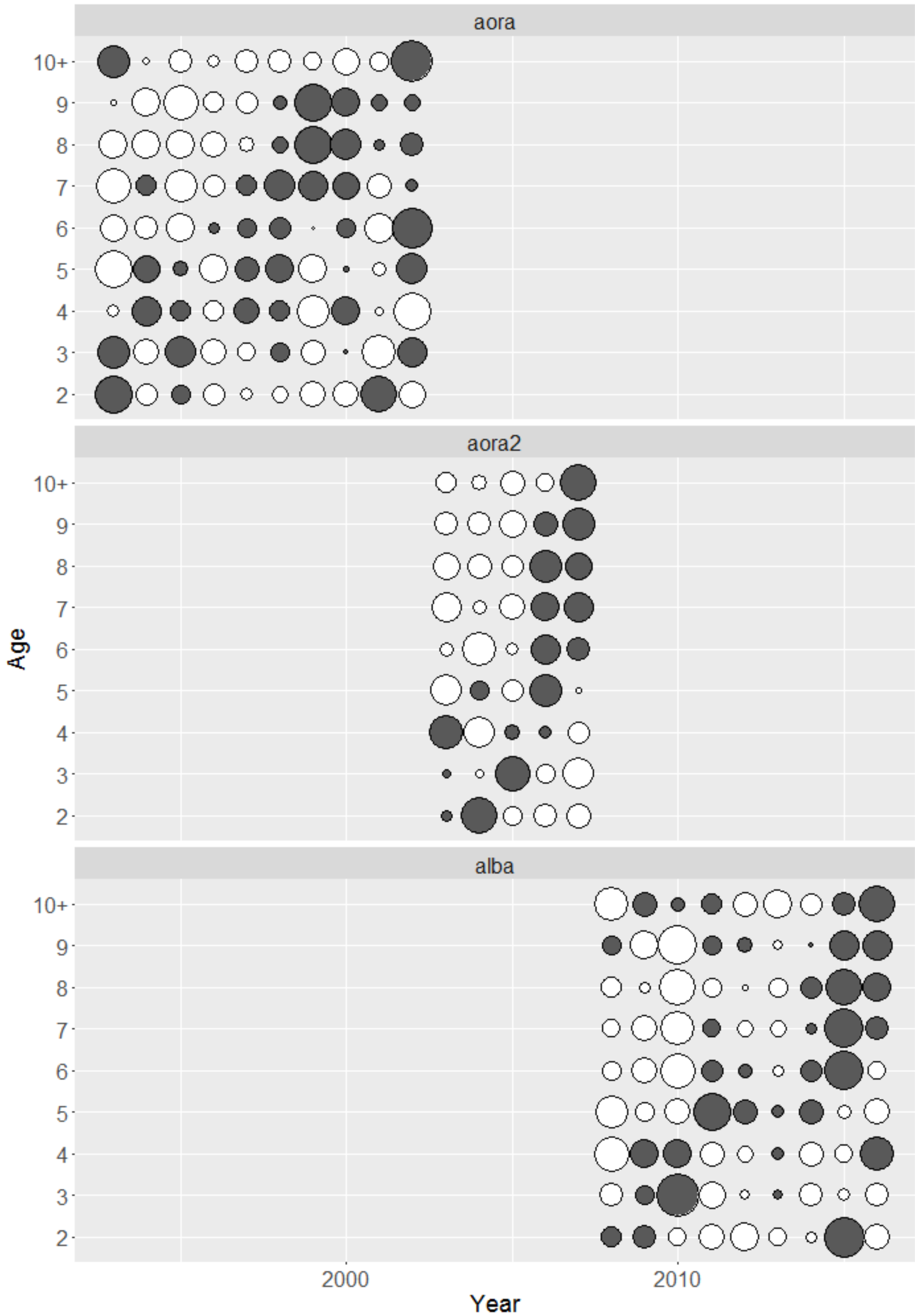

Figure 3.9.4: West of Kintyre. Mean standardised survey catch at age. Dark shaded circles represent above average values and white circles below average.

Figure 3.9.5: West of Kintyre. Mean standardised survey and commercial catch at age comparison. Upper plot: Aora survey, middle plot: Aora II survey, lower plot: Alba survey.

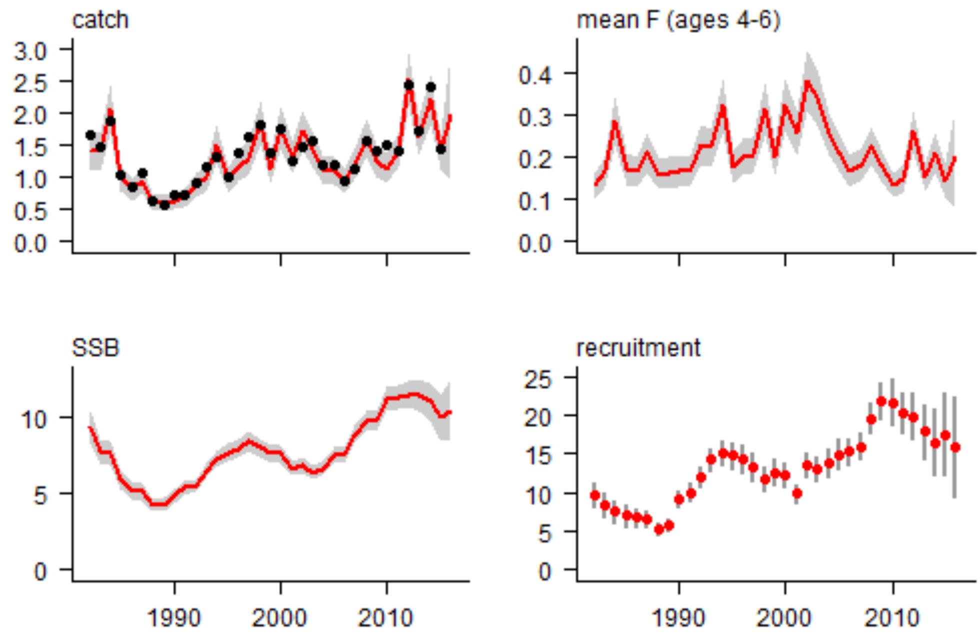

Figure 3.9.6: West of Kintyre. TSA stock summaries from the final TSA run. Catch and SSB are in thousand tonnes and recruitment (age 3) in millions. Catch figure shows both model estimates (red line) and input data (points). Estimates are plotted with approximate 95 % confidence intervals.

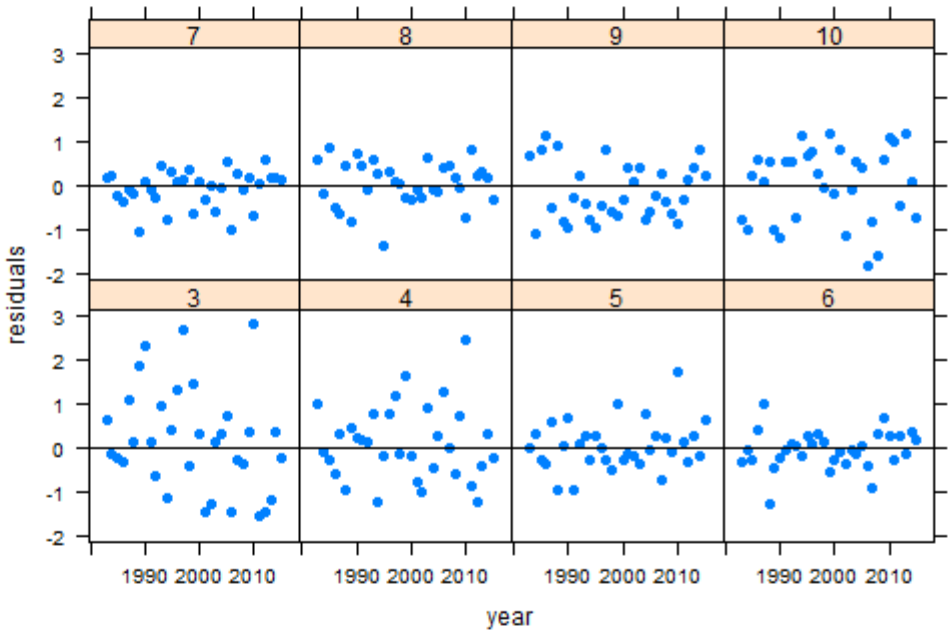

Figure 3.9.7: West of Kintyre. Standardised catch residuals by age from the final TSA run.

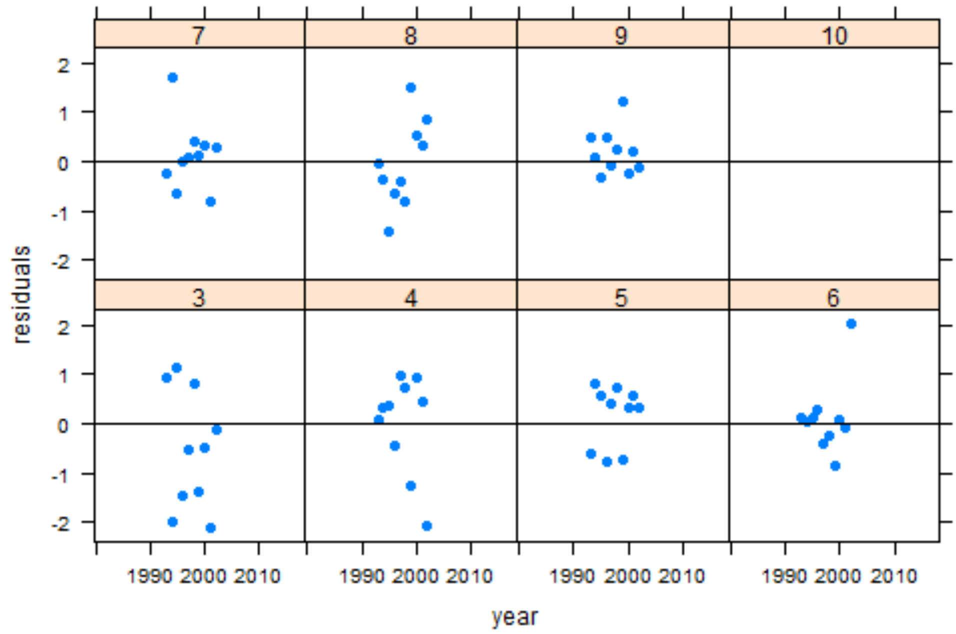

Figure 3.9.8: West of Kintyre. Standardised survey residuals by age (Aora survey) from the final TSA run.

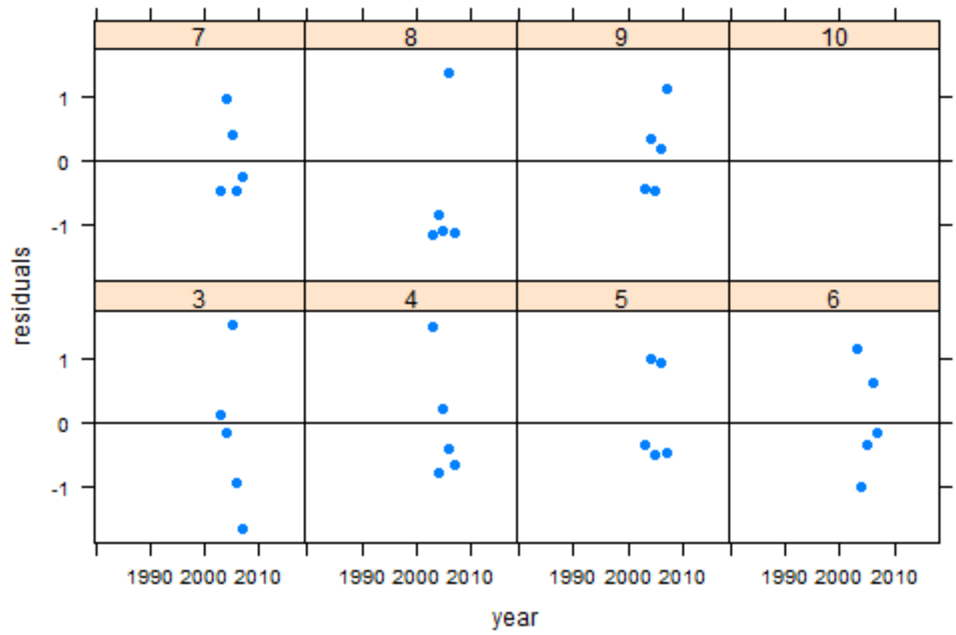

Figure 3.9.9: West of Kintyre. Standardised survey residuals by age (Aora II survey) from the final TSA run.

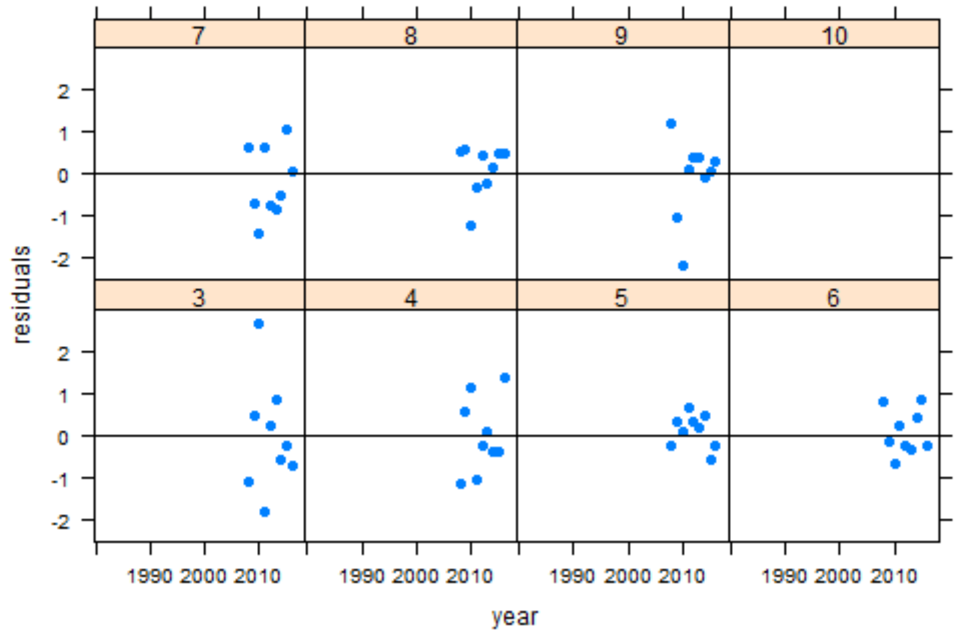

Figure 3.9.10: West of Kintyre. Standardised survey residuals by age (Alba survey) from the final TSA run.

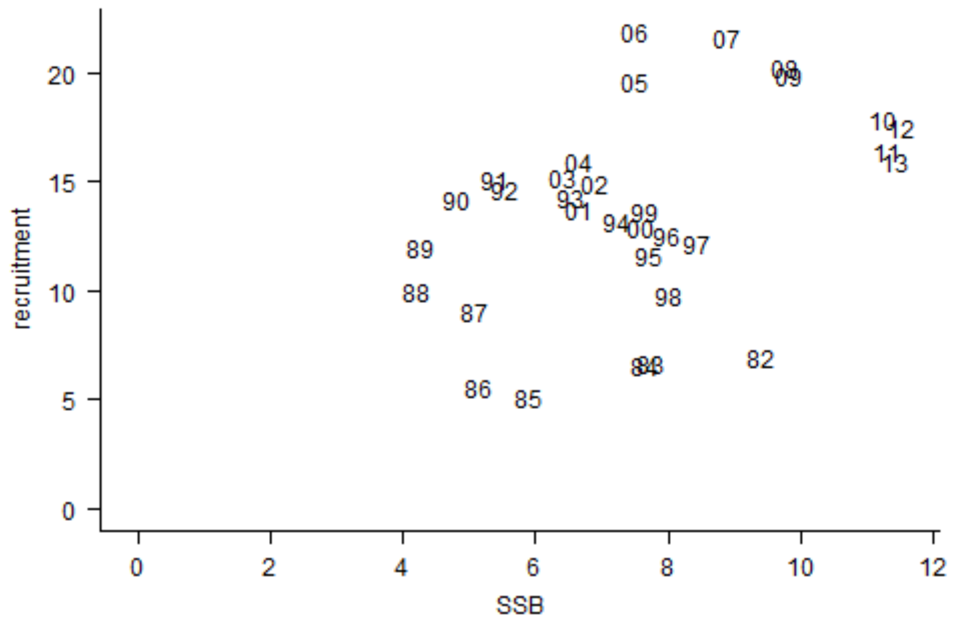

Figure 3.9.11: West of Kintyre. Stock-recruit plot from the final TSA run. Recruitment (age 3) is in millions and SSB in thousand tonnes. Values are labelled with year class.

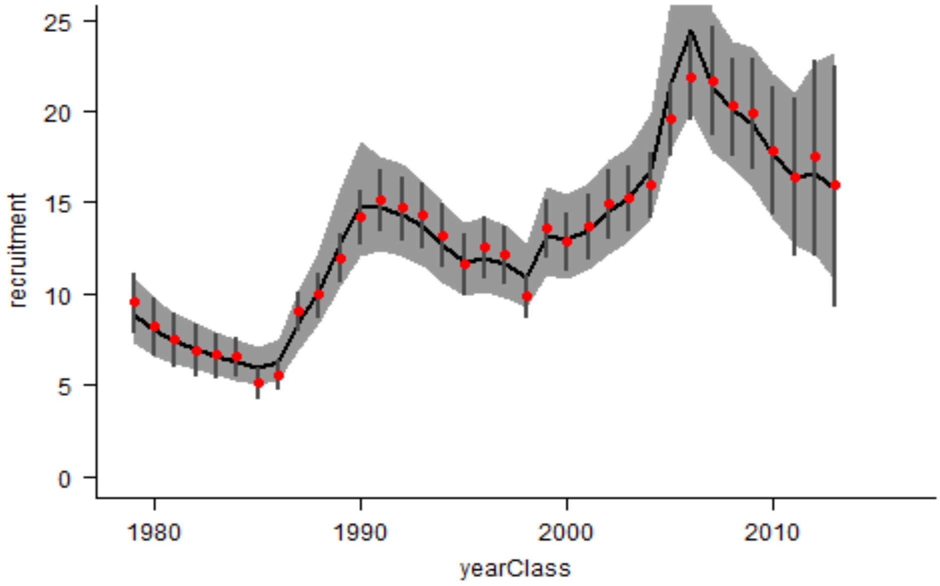

Figure 3.9.12: West of Kintyre. Estimated recruitment time-series from the final TSA assessment. Red points give estimated values with grey bars indicating approximate pointwise 95% confidence intervals. The black line (also with 95% CI) shows the underlying random-walk recruitment model estimated by TSA.

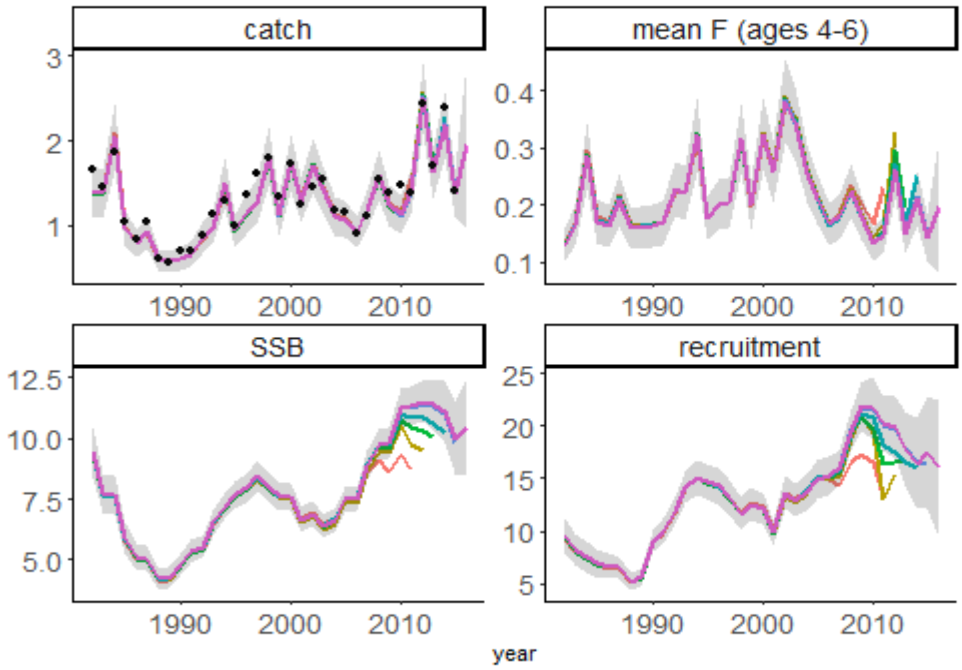

Figure 3.9.13: West of Kintyre. Estimates of Catch, Mean $F_{4\text{-}6}$, SSB and Recruitment with final run 95% confidence intervals (grey shading) from retrospective TSA runs. Catch and SSB are in thousand tonnes and recruitment in millions.

Figure 3.9.14: West of Kintyre. Comparison of final assessment results with previous assessment conducted in 2011. Recruitment is in thousands. SSB is shown as mean standardised (over the common time period) to allow for comparison between results in live weight (current assessment) and muscle weight (2011 assessment).