An initial comparison of the performances of simple management procedures compared to complex assessments for some ICES stocks

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Abstract

These analyses aim to compare the fishery and resource consequences of management recommendations based on complex annual resource assessments to those based on simple empirical management procedures (MPs), which in the cases considered use only the annual abundance estimates from a single survey. The 2010 ICES assessments of the stocks of North Sea Plaice and Sole in Subarea IV are used for the investigation. The MPs are selected from the results of simulations based only on the resource information available in 1990. Their performances are then compared to what actually transpired over the 1990 to 2009 period under advice arising from the regular ICES assessments. For Plaice, almost without exception the MPs' performances dominate what actually eventuated for every performance statistic: higher catches, greater final spawning biomass, lesser lowest spawning biomass during the 20 years, lower average fishing mortalities, and lesser inter-annual variation in both catch and fishing mortality. For Sole these results are qualitatively duplicated, except for marginally smaller catches in some cases. In circumstances for ICES stocks where there may be difficulties in sustaining the level of sampling required for complex annual assessments, such as annual ageing of the catch, because of diminishing resources, these results are sufficiently promising to suggest that they be extended, in particular to further stocks, to confirm whether they might indeed provide an defensible alternative approach to the provision of scientific management advice.

1 Introduction

ICES Working Groups have generally based scientific management advice for more valuable stocks on regular (often yearly) assessments. These stock assessments using age-structured population models such as ADAPT-VPA, XSA and SAM, are often very complex and require a substantial amount of expertise, time and effort. The assessment process is further complicated by decisions regarding which data to include in the analyses, and how these data are incorporated in the objective function being minimized to fit the population model.

However a detailed annual stock assessment may not be necessary to achieve management goals and may constitute an inappropriate use of limited resources. Is there a simpler, more efficient, way of providing reliable management advice? This question is all the more relevant at this time, with diminishing resources raising questions in ICES over whether annual ageing of catches required for assessment methods such as XSA can be sustained.

This paper performs initial analyses to investigate whether simple empirical management procedures (MPs) might perform as well as these complex annual assessments in achieving management goals. This approach, also known as Management Strategy Evaluation (MSE), has established itself as a powerful fisheries management tool to assist meet multiple management objectives in a manner that checks robustness to uncertainty for compatibility with the Precautionary Approach (De Oliveira *et al*. 2010). The 2010 ICES assessments of the stocks of North Sea Plaice and Sole in Subarea IV (ICES WGNSSK Report 2010) are used as the basis to compare these two management approaches. The comparison consists of four steps.

I) *Deterministic "hindsight" projections*

Three simple empirical MPs are each tuned to achieve over the last 20 years (1990 to 2009) the same final (2009) spawning biomass as estimated by the assessments. Since these projections may each follow a different trajectory to that suggested by the assessments, some assumptions are needed to be able to effect the computations.

i) In allocating the annual catch amongst the different ages, the same selectivity-at-age as estimated in the assessment for the year concerned is assumed to apply.

ii) If spawning biomass differs from that in the assessment, recruitment would presumably do so too. A stock-recruitment relationship is fitted to the output from the assessment, with an associated multiplicative residual calculated for each year to reflect the difference between the actual (assessment) recruitment for that year and the value suggested by the stock-recruitment relationship fitted. In these "hindsight" projections, for which the spawning biomass in a particular year may differ from that in the assessment, the key assumption made is that the ***same*** multiplicative residual will apply to the expected recruitment calculated from the estimated stock recruitment relationship. Thus, for example, if the recruitment indicated by the assessment for 1996 was 20% above the value suggested by the fitted stock-recruitment relationship, in any other projection this same 20% will be added to the recruitment predicted by the stock-recruitment relationship for that year, given the projected spawning biomass that year.

iii) Some of the MPs make use of the annual abundance estimates from a survey. Those estimates will differ from the results expected from the best fit of the assessment model to these data in the assessment process. As in ii) above, the assumption made for the projections, for which the underlying abundance under an MP may differ from that for the assessment itself, is that the multiplicative residual for the assessment applies also to the survey estimate which would have resulted under the MP for the year concerned.

These MPs with their associated tunings are referred to as "hindsight" MPs, as they have the benefit of hindsight in "knowing" what will happen in the next 20 years in terms of uncertainties (residuals related to recruitments and survey sampling errors.

II) *Stochastic "forecast" projections of "hindsight" MPs.*

If one had been choosing an MP twenty years ago, one would not have had the benefit of the "hindsight" above at that time. Rather than knowing exactly what recruitment residual will apply each year in the future, projections have to assume that these will be drawn at random each year from distributions estimated from fits of stock-recruitment relationships to the assessment results available at that time (which are taken here to be the 2010 assessment results up to 1989). Similar assumptions need to be made about the abundance estimates forthcoming from future surveys.

When the "hindsight" MPs are applied under these stochastic "forecast" conditions, rather than with exact knowledge about the future, their performance deteriorates, in particular in often yielding final biomasses after 20 years which are considerably below those which actually eventuated. The purpose of this step is to check whether the performance of these "hindsight" MPs would have been considered sufficiently acceptable to have led to their implementation 20 years ago.

III) *Use of stochastic "forecast" projections to tune MPs*

This step involves selecting alternative tunings of the three simple empirical MPs considered in step I) that might have led to their being considered acceptable 20 years ago. The stochastic projections are used to select control parameters for these MPs that achieve a spawning biomass distribution in 20 years time which at the lower 2.5% level is at least as large that which the assessment indicates to have actually resulted. These more conservative MPs are termed "forecast" MPs.

IV) *Performance of selected "forecast" MPs under "hindsight" projections*

In this final step, the "forecast" MPs selected at step III) are applied in conjunction with the deterministic "hindsight" projections (the residuals that actually "occurred") to determine how well those MPs would have managed the fisheries considered. The fundamental question to be addressed is how do the resultant averages catches and fishing mortalities, their interannual variability, and the final spawning biomass after 20 years compare to what was achieved in practice under management based on the use of advice arising from annually updated assessments.

2 Technical specifications of projections

The projection period spans the last twenty years of the 2010 ICES assessments, i.e. from 1990 to 2009. Therefore, projections commence in 1990 and are moved forward year by year by first obtaining the TAC according to a particular MP based on new survey biomass data, from which the corresponding fishing mortality, F_y, rate can be computed for that year given the selectivity-at-age vector selected. The population numbers for the next year can then be computed. The number of recruits (1-year olds) for the next year is then calculated using a Beverton-Holt stock-recruit relationship (see Appendix A for specifications of assessment data and parameters used in the projections).

Population numbers-at-age are projected forward from 1990 to 2009 using the following equations which assume continuous fishing throughout year (Baranov equation):

$$N_{y+1,a\min} = R_{y+1} \tag{1}$$

$$N_{y+1,a+1} = N_{y,a} e^{-(M_a + S_{y,a} F_y)} = N_{y,a} e^{-Z_{y,a}} \quad \text{for } a_{\min} \leq a < m-2 \tag{2}$$

$$N_{y+1,m} = N_{y,m-1} e^{-(M_{m-1} + S_{y,m-1} F_y)} + N_{y,m} e^{-(M_m + S_{y,m} F_y)} \tag{3}$$

where

$N_{y,a}$ is the number of fish of age *a* at the start of year *y*,

M_a denotes the natural mortality rate on fish of age *a*, which is input,

$S_{y,a}$ is the age-specific selectivity for year *y*, which is input (deterministic) or randomly sampled (stochastic),

F_y is the fishing mortality for year *y*, which is estimated,

$m = 10$ is the maximum age considered (taken to be a plus-group), and

$a_{\min} = 1$ is the minimum age considered.

Stock-recruitment relationship:

The "future" number of recruits at the start of year *y* from 1990 to 2009 is related to the spawning stock size by a stock-recruitment relationship. Two forms of such a relationship are considered. The first is the Beverton-Holt form

$$R_y = \frac{\alpha\, B_{y-1}^{sp}}{\beta + B_{y-1}^{sp}} e^{\varsigma_y} \tag{4}$$

where

α and β are the stock-recruitment parameters estimated by minimizing the negative of the log likelihood in equation (A.13) of Appendix 1, which are input,

ς_y are the corresponding recruitment residuals which are either input for the deterministic projections, or

$\varsigma_y \sim N(0,(\sigma^R)^2)$ for the stochastic projections with standard deviation of $\sigma^R = 0.5$ for both stocks (this value was used because it is close to the estimated standard deviation and for the sake of simplicity), and

B^{sp}_{y-1} is the spawning biomass in year $y-1$, given that

$$B^{sp}_y = \sum_{a=1}^{10} f_a w^S_{y,a} N_{y,a} \tag{5}$$

where $N_{y,a}$ is the projected number of fish in year *y* of age *a* given by equations (1), (2) and (3), and

$w^S_{y,a}$ are the population weights-at-age for each year used in the 2010 ICES assessments, and

f_a is the proportion of fish of age *a* that are mature, which is input.

The second is a two-line (or "hockey stick") form

$$\begin{aligned} B^{sp}_y \geq B^0: \quad & R_y = \alpha e^{\zeta_y} \\ B^{sp}_y < B^0: \quad & R_y = (\alpha B^{sp}_{y-1} / B^0) e^{\zeta_y} \end{aligned} \tag{6}$$

where B^0 is the minimum spawning biomass over the period under consideration, and α is estimated as above (which will yield the geometric mean of the recruitment estimates over this period).

Catch equation:

Once a TAC for year *y* is generated by the MP, the corresponding fishing mortality rate, F_y, can be computed. When using the Baranov formulation, the total number of fish caught of age a in year *y* is given by

$$C_{y,a} = N_{y,a} \frac{S_{y,a} F_y}{Z_{y,a}} (1 - e^{-Z_{y,a}}) \tag{7}$$

where F_y is computed using the bisection method such that

$$C_y = \sum_{a=1}^{10} w_{y,a}^C C_{y,a} \tag{8}$$

where C_y is the total annual catch (TAC) corresponding to a chosen harvesting strategy, and

$w_{y,a}^C$ are the catch weights-at-age for each year taken from the 2010 ICES assessment, which are input.

Survey biomass:

The future biomass corresponding to survey index *i* is given by

$$B_y^{sur\_i} = \sum_{a=1}^{10} S_a^{sur\_i} w_{y,a}^S N_{y,a} \tag{9}$$

where

$w_{y,a}^S$ denote the population weights-at-age for each year used for the 2010 ICES stock assessment, which are input, and

$S_a^{sur\_i}$ is the fishing selectivity corresponding to the survey index *i*.

Projected survey data

Future survey data are generated assuming the same residuals as inferred from the adjusted 2010 XSA assessment

$$I_y^i = q^i B_y^{sur\_i} e^{\varepsilon_y^i} \tag{10}$$

where

$B_y^{sur\_i}$ is the model estimate of projected survey biomass, given by equation (9),

q^i is the constant of proportionality for survey abundance series *i* estimated using equation (A.19) in Appendix A, and

ε_y^i are the residuals given by equation (A.20) in Appendix 1 for the deterministic projections, or $\varepsilon_y^i \sim N(0,(\sigma^i)^2)$ for the stochastic projections, where σ^i are either given by equation

(A.21), or input. For these projections the standard deviation was fixed to $\sigma^i = 0.2$ for both stocks for simplicity, the value being approximately equal to the estimated standard deviation.

Projected commercial selectivity:

The commercial selectivity-at-age vectors for future years (1990 onwards) are sampled randomly from past (1980 to 1989) XSA estimates.

Projected weights:

The population, $w^S_{y,a}$, and catch, $w^C_{y,a}$, weights-at-age for future years (1990 onwards) are set equal to the average weight for each age over the last three years prior to the projection period, i.e.,

$$w_{y,a} = 1/3 \sum_{y'=1987}^{1989} w_{y',a} \text{ for y>1989.}$$

3 Candidate Management Procedures

Some very simple empirical management procedures, based on trends in survey indices of abundance, are investigated. These simple MPs are particularly useful in data-poor situations where data are limited (Geromont and Butterworth, 2010), rendering a model-based MP unsuitable, or where there is too much variability about the data, in which case a more complex model-based MP may well follow noise rather than trend. Furthermore, the very simple empirical rules are easy to understand, test and apply and have been shown to be as robust to uncertainty as their model-based counterparts in a number of cases (for example in the development of MPs for Southern Bluefin Tuna – CCSBT, 2010). The main disadvantage of empirical MPS are that there are no estimates of resource abundance and other management reference points on which to base TACs.

For example “derivative” or “slope”-based MPs utilize the trend in a limited subset of data (typically the most recent 5 years of survey biomass estimates) for input. The annual TAC is simply moved up or down from where it was the previous year without knowledge of where the resource might be in relation to maximum sustainable yield level or other conventional management reference points. Note that in implementation for relatively data-rich stocks such as North Sea Plaice and Sole that are considered here, a simple MP approach like this would be underpinned by a full resource assessment;

the former provides ongoing yearly management advice, while the latter is re-considered at multi-year intervals to re-check the appropriateness of the MP and if necessary to adjust some of its parameters.

3.1 Constant catch MP

At the one extreme, this is the simplest of all empirical MPs and requires no data to set the annual TAC. The future TAC given by

$$TAC_{y+1} = TAC^{target} \tag{11}$$

where TAC^{target} is chosen such that the projected population spawning biomass in 2009 reaches some target level $B^{sp}_{2009} = B^{target}$. For the "hindsight" projections, the target biomass was chosen to be equal to the final spawning biomass estimated in the adjusted 2010 ICES assessment, $B^{target} = B^{XSA}_{2009}$, to facilitate comparison between the MP and assessment-based management approaches.

For the stochastic "forecast" projections, a search routine is used to find the constant catch that reaches the target for each simulation, an approach suggested by Bentley and Langley (2011). The desired constant level for future catches is selected from the resulting distribution as the one that will provide adequately risk averse performance under the uncertainty incorporated in the projections (the 2.5%-ile value was chosen for these projections).

Note: A constant catch harvesting strategy is not recommended as there is no feedback-control mechanism built into this type of MP. It does however give a ball-park figure of the average yield that can be expected during the projection period given a chosen target, which is useful for later comparison of the different candidate MPs.

3.2 Survey slope based MP

For this type of MP, limited data are used in the MP formula to ascertain recent trends in biomass, with the TAC being moved up or down depending on whether the perceived trend is positive or negative. The TAC for the next year is given by

$$TAC_{y+1} = TAC_y(1 + \lambda s_y) \tag{12}$$

where TAC_y is the TAC in year *y*,

λ is a control parameter that reflects how strongly the TAC is adjusted in response to the perceived trend in resource biomass, and

s_y is a measure of the trend in the survey abundance index given by the slope of the linear regression of $\ln I^i_{y'}$ against y' for years $y' = y - p, y - p + 1, ..., y$ for abundance index I^i, and

p is the number of years over which the slope is calculated. Note that if p is too small the trend estimates would fluctuate too much (tracking noise) and if p is too large the MP would not be able to react quickly enough to recent trends in resource abundance. A value

For the first year of the projection period an appropriate "starting level", $TAC*$, must be chosen (not necessarily equal to the actual TAC that year) . This is specified as $TAC* = x\%TAC_n$, where *n* is the last year of the assessment period and *x* is a control parameter that reflects how aggressive/conservative the MP should be. The choice of this starting point is important for the performance of the MP because a starting level that is too low will result in an unrealistically large drop in TAC in the first year of management (unrealistic because it would not be accepted in practice), while a starting point that is too high necessitates subsequent severe cuts in the TAC.

In addition, with the exception of the starting level TAC, TAC_{n+1}, all subsequent TACs are restricted to increase/decrease by at most *v*% from the previous year, i.e. let

$$TAC_{change} = (TAC_{y+1} - TAC_y) / TAC_y \tag{13}$$

then

$$TAC_{y+1} = TAC_y + v\%TAC_y \qquad \text{if } TAC_{change} > v\%$$

or

$$TAC_{y+1} = TAC_y - v\%TAC_y \qquad \text{if } TAC_{change} < -v\%$$

A restriction of 20% inter-annual variation in catch was chosen for base case runs in order to be reasonably consistent with the maximum annual changes in observed catches (landings plus discards).

3.3 Target based MP

This type of MP is based on moving resource abundance to a chosen target level for some abundance index *I*. The form of the Tier 4 control rule in Wayte (2009) is used here. The TAC is adjusted up or down depending whether the most recent abundance index (in these cases survey biomass estimate) is above or below the target survey.

The TAC for the next year is given by

$$TAC_{y+1} = TAC^{target}[w + (1-w)(\frac{I^{recent} - I^0}{I^{target} - I^0})] \tag{14}$$

if $I^{recent} \geq I^0$ and

$$TAC_{y+1} = wTAC^{target}\left(\frac{I^{recent}}{I^0}\right)^2 \tag{15}$$

if $I^{recent} < I^0$

where I^{recent} is the average survey over the most recent four years,

$I^{target} = x\%I^{ave}$ is the desired target value for the survey index of abundance,

$I^0 = y\%I^{ave}$ is a lower survey abundance index level below which the TAC decreases to zero rapidly,

$I^{ave} = 1/5\sum_{y=1985}^{1989} I_y$ is an average historic survey abundance index value,

TAC^{target} is the catch target (when $I^{recent} = I^{target}$), and

w is a fraction that defines the catch level when $I^{recent} = I^0$.

A simplified, commonly used, form of equation (14) is obtained by setting *w=0*

$$TAC_{y+1} = TAC^{target}(\frac{I^{recent} - I^0}{I^{target} - I^0}) \tag{16}$$

Here, the catch is set to zero when the abundance index reaches its lower limit, I^0. At the other extreme, setting $w = 1$ results in the constant catch harvesting strategy of equation (11).

However, the formulation given by equation (14) allows for a non-zero catch of $wTAC^{target}$ when $I^{recent} = I^0$, which has the effect of dampening the inter-annual variation in catches, thereby stabilizing the output from the MP. Setting $w = 0$ would necessitate a steeper slope of the linear relationship given by equation (16), leading to more variable catches. On the other hand, setting $w = 1$ would result in no inter-annual fluctuations in catch, but also no adjustment of catch in response to changes in survey abundance indices. A suitable trade-off between the level of feedback control and inter-annual catch variation was sought and a value of $w = 0.5$ was chosen for the deterministic retrospective projections considered here, so that equation (14) becomes

$$TAC_{y+1} = 0.5TAC^{target}\left[1 + \left(\frac{I^{recent} - I^0}{I^{target} - I^0}\right)\right] \tag{17}$$

In addition, a restriction for maximum allowed inter-annual change in catch is imposed as per equation (13).

Figure 1 illustrates these forms of relationship for different values of the control parameter *w*.

4. Results

The statistics reported for comparison of performance of the MPs over the period from 1990 to 2009 are:

i) average annual catch over the projection period, $\overline{TAC}$,

ii) average annual variation of catch (variation given by modulus of change in catch as a proportion of previous catch) over the projection period, $\overline{\Delta TAC}$,

iii) the average annual fishing mortality rate, $\overline{F}$,

iv) the average annual variation (given by modulus of change) in fishing mortality, $\overline{\Delta F}$,

v) minimum spawning biomass as a fraction of the target biomass, $\min B_y^{sp} / B^{target}$ where B^{target} corresponds to the 2009 spawning biomass estimated in the adjusted 2010 ICES assessments for North Sea Plaice or Sole in Subarea IV, and

vi) final (2009) spawning biomass expressed in the same way as detailed in v).

Three types of MPs with different harvest control rules are investigated:

- Constant catch MP, i.e. no data used in the TAC setting rule (equation (11)).
- Survey slope based MP, using trend information in the survey index of abundance to increase/decrease TACs from one year to another in accordance to a positive/negative trend (equation (12)).
- Target based MP, in which a target survey estimate is specified and the future TAC is adjusted each year to approach, and eventually maintain, the target (equation (14)).

Two stock-recruit functions are investigated:

- A Beverton-Holt stock-recruit curve with a steepness fixed at 0.9.
- A simple 2-line ("hockey-stick") stock-recruitment relationship.

For North Sea Plaice and Sole in Subarea IV, the survey data used in the TAC setting rules are the BTS-Isis index, aggregated over all ages.

Results are shown in Tables 1 to 4 and Figures 2 to 6 for North Sea Plaice, and Tables 5 to 8 and Figures 7 to 11 for Sole in Subarea IV. Deterministic ("hindsight") and stochastic ("forecast") projections are performed starting in year 1990 to 2009. One thousand simulations were run for the stochastic analyses. Four sets of results are shown for each stock:

- Deterministic "hindsight" projections with MPs tuned to hit the 2009 target spawning biomass exactly (Tables 1a, 1b, 5a and 5b and Figures 2 and 7).

- Stochastic "forecast" projections of "hindsight" MPs (Tables 2a, 2b, 6a and 6b).

- Stochastic "forecast" projections used to tune the MPs: those MPs that showed the best performance while at the lower 5%-ile achieving a final spawning biomass which was equal to or greater than that actually achieved as indicated by the 2010 ICES assessment, were selected and are termed "forecast" MPs (Tables 3a, 3b, 7a and 7b and Figures 3, 4, 8 and 9).

- Deterministic "hindsight" projections, but here under the "forecast" MPs (Tables 4a, 4b, 8a and 8b and Figures 5 and 10).

Throughout, the Tables contrast values of the performance statistics that were actually achieved to those for the three types of MP. Figure 6 provides a graphical summary of the performance statistics for the various tuned “forecast” MPs for North Sea Plaice from projections over 1990 to 2009: (a) shows results for the stochastic “forecast” projections, while (b) shows these for the “hindsight” projection for which the stock-recruitment and survey residuals found in the 2010 ICES assessments are taken to apply. Figure 11 shows the corresponding results for Sole in Subarea IV.

5. Discussion and conclusions

The “hindsight” MPs for which results are reported in Tables 1 and 5 outperform what was achieved in practice for total catch over the 20 year period considered, despite finishing the period with the same spawning biomasses as do the ICES assessments. The constant catch MP performs best in this respect, though the other two types of MP are not far behind. The other performance statistics are nearly always better for the MPs than was achieved historically.

The larger catches with the same target biomass arise in part because the Beverton-Holt stock-relationship with h = 0.9 that is assumed reflects an increase in recruitment over the range of spawning biomasses that occur over the 1990-2009 period, so that a harvest pattern that leads to that biomass being nearer the upper end of that range will result in improved recruitment and hence greater productivity than historically. The actual best estimates of h from the assessment data available up to 1990 are actually higher than 0.9, and the decision to use 0.9 was taken given conventional reluctance among scientists to buy into a relationship that drops below its pristine level only at very low biomass. However, particularly for the North Sea Plaice, this factor contributes to the “larger catch” behaviour mentioned above, and the reason for introducing the 2-line (“hockey-stick”) relationship as well was as a form of robustness check in circumstances that would not evidence this feature of greater productivity at larger spawning biomass (as is more consistent with the data).

Despite this good performance, these “hindsight” MPs would not have been viable candidates for implementation in 1990. The reasons are readily evident from Tables 2 and 6. For example, under the stochastic “forecast” projections that take account of future uncertainty in recruitment levels, the median final spawning biomass for North Sea Plaice in 2009 for the “hindsight” constant catch MP is zero. Though for the other “hindsight” MPs as well as for Sole the behavior is a little better, nevertheless nearly all the MPs exhibit lower 2.5%-iles for spawning biomass that go very low and even to zero.

However once these MPs are tuned under the stochastic “forecast” projections to yield final spawning biomass distributions whose lower 5%-iles are at least as large as occurred in reality, this problem is obviated and the associated “forecast” MPs are certainly such as might have been accepted for implementation in 1990. In terms of medians of performance statistics, these MPs still achieve better performance in nearly all respects (i.e. “dominate”) what was achieved in practice for North Sea Plaice (Table 3). For Sole (Table 7) virtually the same applies, the exception being that the average catch is some 10% less, though this comes with the advantage of a final spawning biomass improvement by a factor of about double or more. Tables 4 and 8, where these “forecast” MPs are applied under the “hindsight” projections, show the same patterns.

Figures 6 and 11 provide useful summaries of these performance statistics in graphical form. The domination of the “forecast” MPs performance over actual events for North Sea Plaice is readily evident, though for Sole again the MPs’ catch performance is slightly weaker. Of the different types of MPs, the constant catch types reflect the smallest total catches, and in any case are unlikely candidates in reality because of their lack of feedback features to provide robustness to other uncertainties which have not been considered here. The catch performance for the slope and target based MPs is almost equal to what was achieved historically for Sole, and overall there appears little to choose between these two MP types in terms of performance.

In general these results are similar to those obtained in simulation studies by Punt (1993), which showed that compared to simpler management approaches based on production models, attempts to take age-structure information into account through VPA in recommending catch limits led to greater variability in those limits without any corresponding enhancement of performance in terms of resource conservation.

In conclusion, these results seem sufficiently promising to suggest that they be extended, in particular to further stocks, to confirm whether they might indeed provide a defensible alternative approach to the provision of scientific management advice. At present for ICES stocks, because of diminishing research resources, there may be difficulties in sustaining the level of data input required for complex annual assessments, such as annual ageing of the catch. This raises the question of whether such complex assessments can continue to serve as the primary basis to provide scientific advice on catch limits, so that there is a need to explore alternative possibilities as done here.

This is not to suggest that complex assessments can be abandoned. Rather they still need to be conducted from time to time to provide the updated representations of the underlying resource dynamics that serve as the basis for repetitions of the process of re-selecting simple MPs at regular intervals. Though VPA assessments require annual ageing, if that cannot be continued, various

SCAA/integrated analysis assessment approaches which do not require age data for every year could be used instead.

6. Future Work

- Due to limited time, only two stocks (North Sea Plaice and Sole in Subarea IV) have been investigated thus far (and the parameter choices for the Sole MPs could not be optimized to the same extent as those for Plaice). The highest priority would seem to be the extension of this work to consider more ICES stocks, hopefully to confirm more widespread applicability.
- In comparing performance above, “forecast” MPs were tuned to achieve the same final spawning biomass level at some low percentile (5%) of the distribution of this statistic. Trade-off comparisons might be more readily made if instead tuning was effected to achieve the same total catch over the period.
- The stochastic projection trial exercise should be extended to incorporate more checks of robustness. Aspects to be considered for inclusion in such an extension include first estimation and then model structure uncertainty in the numbers-at-age vector that commences the projections, variability in natural mortality, and a greater number of stock-recruitment relationships.
- In the calculations above, the TAC specified by the MP was assumed to be exactly equal to total removals for the year concerned. Realistic levels of implementation error need to be incorporated into projections.
- At a later stage, if this approach finds wide favour, rather than demonstrations of adequacy based on history, the analyses will need to move on to consider simulations projecting forward from the present time, so as to develop MPs that can be seriously considered for implementation. This could involve extension beyond the simple types of MPs considered here, as well as a wider range of robustness testing.

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Plaice: Subarea IV		**Beverton-Holt stock recruit relationship with h=0.9**		
		MP1	**MP2**	**MP3**
	Observed catches	**Constant catch**	**MP slope: BTS-Isis** $x = 80\%, \lambda = 0.556$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}, I^{target} = 1.1I^{ave}$ $TAC^{target} = 206700$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	145702	185989	152206	156460
$\overline{\Delta TAC}$	0.166	0.016	0.076	0.051
$\overline{F}$	0.735	0.709	0.738	0.726
$\overline{\Delta F}$	0.202	0.186	0.212	0.170
$B^{sp}_{2009} / B^{target}$	1.000	1.000	1.013	1.047
$\min B^{sp}_y / B^{target}$	0.491	0.610	0.429	0.451

Table 1a: Comparison of North Sea Plaice results for deterministic "hindsight" projections under a Beverton-Holt stock-recruit relationship when using only the BTS-Isis aggregated index in "hindsight" MPs (see text for details of the MP control parameters). Units are tons where applicable.

Plaice: Subarea IV		2-line stock recruit relationship		
		MP1	**MP2**	**MP3**
	Observed catches	**Constant catch**	**MP slope: BTS-Isis** $x=80\%, \lambda=0.562$ $p=4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0=0.2I^{ave}, I^{target}=1.1I^{ave}$ $TAC^{target}=206700$ $w=0.49$ (max 20% ΔTAC)
$\overline{TAC}$	145702	178293	151582	154935
$\overline{\Delta TAC}$	0.166	0.018	0.075	0.051
$\overline{F}$	0.735	0.634	0.737	0.722
$\overline{\Delta F}$	0.202	0.198	0.217	0.172
B^{sp}_{2009}/B^{target}	1.000	1.000	1.023	0.997
$\min B^{sp}_y/B^{target}$	0.491	0.680	0.422	0.445

Table 1b: As for Table 1a, but here when projecting with a 2-line stock-recruit relationship.

Plaice: Subarea IV		**Beverton-Holt stock recruit relationship with h=0.9**		
	Observed catches	**Constant catch** $TAC^{target} = 185989$	**MP slope: BTS-Isis** $x = 80\%, \lambda = 0.556$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2 I^{ave}$ $I^{target} = 1.1 I^{ave}$ $TAC^{target} = 206700$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	145702	185989 (185989, 185989)	174343 (107374, 214871)	169445 (91831, 218102)
$\overline{\Delta TAC}$	0.166	0.016 (0.016, 0.016)	0.078 (0.057, 0.118)	0.067 (0.048, 0.143)
$\overline{F}$	0.735	3.146 (0.197, 7.270)	0.317 (0.225, 3.220)	0.351 (0.227, 6.398)
$\overline{\Delta F}$	0.202	0.283 (0.142, 0.471)	0.186 (0.126, 0.341)	0.196 (0.124, 0.442)
$B^{sp}_{2009} / B^{target}$	1.000	0.000 (0.000, 12.315)	5.468 (0.000, 10.792)	4.604 (0.000, 10.134)
$\min B^{sp}_y / B^{target}$	0.491	0.000 (0.000, 1.013)	0.853 (0.000, 0.950)	0.798 (0.000, 0.955)

Table 2a: Comparison of results for stochastic "forecast" projections for North Sea Plaice under a Beverton-Holt stock-recruit relationship when using only the BTS-Isis aggregated index in the slope and target type "hindsight" MPs. Management quantities shown are medians with associated 95% probability intervals in parenthesis. 1000 simulations were performed. Units are tons where applicable.

Plaice: Subarea IV		2-line stock recruit relationship		
	Observed catches	**Constant catch** $TAC^{target} = 178293$	**MP slope: BTS-Isis** $x = 80\%, \lambda = 0.562$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}$ $I^{target} = 1.1I^{ave}$ $TAC^{target} = 206700$ $w = 0.49$ (max 20% ΔTAC)
$\overline{TAC}$	145702	178293 (178293, 178293)	149568 (96345, 172055)	149868 (87507, 172475)
$\overline{\Delta TAC}$	0.166	0.018 (0.018, 0.018)	0.078 (0.057, 0.132)	0.062 (0.047, 0.152)
$\overline{F}$	0.735	4.529 (0.267, 7.220)	0.354 (0.258, 4.056)	0.419 (0.270, 6.555)
$\overline{\Delta F}$	0.202	0.332 (0.138, 0.502)	0.186 (0.126, 0.341)	0.197 (0.119, 0.434)
$B_{2009}^{sp} / B^{target}$	1.000	0.000 (0.000, 4.102)	2.695 (0.000, 4.890)	2.050 (0.000, 4.529)
$\min B_y^{sp} / B^{target}$	0.491	0.000 (0.000, 1.013)	0.798 (0.000, 0.949)	0.698 (0.000, 0.953)

Table 2b: As for Table 2a, but here when projecting with a 2-line stock-recruit relationship.

Plaice: Subarea IV		Beverton-Holt stock recruit relationship with h=0.9		
	Observed catches	**Constant catch** $TAC^{target} = 160634$ Median constant catch required to reach target for each simulation: 184068 (160634,216004)	**MP slope: BTS-Isis** $x = 80\%, \lambda = 1.0$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}$ $I^{target} = 1.1I^{ave}$ $TAC^{target} = 206700$ $w = 0.0$ (max 20% ΔTAC)
$\overline{TAC}$	145702	160634 (160634, 160634)	181650 (137235, 234484)	184272 (126068, 248620)
$\overline{\Delta TAC}$	0.166	0.021 (0.021, 0.021)	0.118 (0.091, 0.148)	0.146 (0.101, 0.191)
$\overline{F}$	0.735	0.200 (0.136, 0.457)	0.238 (0.190, 0.338)	0.214 (0.182, 0.263)
$\overline{\Delta F}$	0.202	0.189 (0.142, 0.295)	0.189 (0.137, 0.260)	0.198 (0.147, 0.265)
$B^{sp}_{2009} / B^{target}$	1.000	9.647 (1.000, 16.739)	7.624 (3.794, 12.943)	8.684 (6.293, 12.808)
$\min B^{sp}_{y} / B^{target}$	0.491	1.013 (0.736, 1.013)	0.902 (0.739, 0.945)	0.893 (0.682, 0.955)

Table 3a: Comparison of results for stochastic “forecast” projections for North Sea Plaice under a Beverton-Holt stock-recruit relationship for the “forecast” MPs. Management quantities shown are medians with associated 95% probability intervals in parenthesis. 1000 simulations were performed. Units are tons where applicable.

Plaice: Subarea IV		**2-line stock recruit relationship**		
	Observed catches	**Constant catch** $TAC^{target} = 146275$ Median constant catch required to reach target for each simulation: 168306 (146275,195181)	**MP slope: BTS-Isis** $x = 80\%, \lambda = 0.61$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2 I^{ave}$ $I^{target} = 1.1 I^{ave}$ $TAC^{target} = 206700$ $w = 0.378$ (max 20% ΔTAC)
$\overline{TAC}$	145702	146275 (146275, 146275)	147736 (122006, 171214)	144947 (120021, 169205)
$\overline{\Delta TAC}$	0.166	0.024 (0.024, 0.024)	0.083 (0.060, 0.113)	0.076 (0.057, 0.105)
$\overline{F}$	0.735	0.216 (0.152, 0.398)	0.322 (0.245, 0.540)	0.316 (0.239, 0.554)
$\overline{\Delta F}$	0.202	0.172 (0.122, 0.248)	0.179 (0.122, 0.275)	0.179 (0.123, 0.282)
$B^{sp}_{2009} / B^{target}$	1.000	4.126 (1.000, 7.238)	3.085 (1.057, 5.261)	3.337 (1.002, 5.362)
$\min B^{sp}_{y} / B^{target}$	0.491	1.013 (0.804, 1.013)	0.831 (0.435, 0.949)	0.794 (0.405, 0.954)

Table 3b: As for Table 3a, but here projecting with a 2-line stock-recruit relationship.

Plaice: Subarea IV		Beverton-Holt stock recruit relationship with h=0.9		
	Observed catches	**Constant catch** $TAC^{target} = 160634$	**MP slope: BTS-Isis** $x = 80\%, \lambda = 1.0$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2 I^{ave}, I^{target} = 1.1 I^{ave}$ $TAC^{target} = 206700$ $w = 0.0$ (max 20% ΔTAC)
$\overline{TAC}$	145702	160634	173748	198740
$\overline{\Delta TAC}$	0.166	0.021	0.120	0.112
$\overline{F}$	0.735	0.235	0.315	0.331
$\overline{\Delta F}$	0.202	0.188	0.207	0.166
$B^{sp}_{2009} / B^{target}$	1.000	10.454	7.782	6.375
$\min B^{sp}_{y} / B^{target}$	0.491	0.921	0.813	0.796

Table 4a: Comparison of results for deterministic "hindsight" projections under a Beverton-Holt stock-recruit relationship when using only the BTS-Isis aggregated index in the "forecast" MPs. Units are tons where applicable.

Plaice: Subarea IV		2-line stock recruit relationship		
	Observed catches	**Constant catch** $TAC^{target} = 146275$	**MP slope: BTS-Isis** $x = 80\%, \lambda = 0.61$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}, I^{target} = 1.1I^{ave}$ $TAC^{target} = 206700$ $w = 0.378$ (max 20% ΔTAC)
$\overline{TAC}$	145702	146275	146550	147666
$\overline{\Delta TAC}$	0.166	0.024	0.089	0.067
$\overline{F}$	0.735	0.306	0.727	0.537
$\overline{\Delta F}$	0.202	0.194	0.208	0.163
$B^{sp}_{2009} / B^{target}$	1.000	2.811	1.413	1.788
$\min B^{sp}_y / B^{target}$	0.491	0.921	0.446	0.529

Table 4b: as for Table4a, but here when projecting with a 2-line stock-recruit relationship.

Sole: Subarea IV		Beverton-Holt stock recruit relationship with h=0.9		
	Observed catches	**Constant catch** $TAC^{target} = 24312$	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.21$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2 I^{ave}, I^{target} = 2 I^{ave}$ $TAC^{target} = 26300$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	24312	23981	23221
$\overline{\Delta TAC}$	0.152	0.005	0.055	0.063
$\overline{F}$	0.908	0.602	0.700	0.799
$\overline{\Delta F}$	0.274	0.302	0.309	0.289
$B^{sp}_{2009} / B^{target}$	1.000	1.000	0.997	0.985
$\min B^{sp}_{y} / B^{target}$	0.519	0.925	0.718	0.541

Table 5a: Comparison of results for deterministic "hindsight" projections for Sole in Subarea IV under a Beverton-Holt stock-recruit relationship when using only the BTS-Isis aggregated index in the MPs selected with hindsight (see the text for details of the MP control parameters) when using a Beverton-Holt stock-recruit relationship. Units are tons where applicable.

Sole: Subarea IV		**2-line stock recruit relationship**		
	Observed catches	**Constant catch** $TAC^{target} = 22465$	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.19$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}, I^{target} = 2I^{ave}$ $TAC^{target} = 25600$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	22465	22700	22504
$\overline{\Delta TAC}$	0.152	0.001	0.045	0.062
$\overline{F}$	0.908	0.525	0.615	0.749
$\overline{\Delta F}$	0.274	0.291	0.306	0.285
$B^{sp}_{2009} / B^{target}$	1.000	1.001	0.991	1.015
$\min B^{sp}_y / B^{target}$	0.519	0.982	0.773	0.571

Table 5b: As for Table 5a, but here projecting with a 2-line stock-recruit relationship.

Sole: Subarea IV		Beverton-Holt stock recruit relationship with h=0.9		
	Observed catches	**Constant catch** $TAC^{target} = 24312$	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.21$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}$ $I^{target} = 2I^{ave}$ $TAC^{target} = 26300$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	24312 (24312, 24312)	23147 (19730, 24836)	21883 (19551, 24554)
$\overline{\Delta TAC}$	0.152	0.005 (0.005, 0.005)	0.042 (0.030, 0.072)	0.044 (0.033, 0.058)
$\overline{F}$	0.908	0.402 (0.219, 3.989)	0.705 (0.301, 4.477)	0.387 (0.283, 1.672)
$\overline{\Delta F}$	0.274	0.177 (0.114, 0.454)	0.226 (0.117, 0.442)	0.156 (0.111, 0.328)
$B^{sp}_{2009} / B^{target}$	1.000	1.448 (0.000, 4.734)	0.432 (0.001, 3.162)	1.654 (0.020, 3.617)
$\min B^{sp}_{y} / B^{target}$	0.519	1.314 (0.000, 2.496)	0.398 (0.000, 2.345)	1.400 (0.007, 2.456)

Table 6a: Comparison of results for stochastic “forecast” projections for Sole in Subarea IV under a Beverton-Holt stock-recruit relationship when using only the BTS-Isis aggregated index in the slope and target type “hindsight” MPs. Management quantities shown are medians with associated 95% probability intervals in parenthesis. 1000 simulations were performed. Units are tons where applicable.

Sole: Subarea IV		2-line stock recruit relationship		
	Observed catches	**Constant catch** $TAC^{target} = 22465$	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.19$ $p = 4$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}$ $I^{target} = 2I^{ave}$ $TAC^{target} = 25600$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	22465 (22465, 22465)	22912 (18954, 24550)	21007 (19120, 23332)
$\overline{\Delta TAC}$	0.152	0.001 (0.001, 0.001)	0.043 (0.029, 0.083)	0.043 (0.032, 0.058)
$\overline{F}$	0.908	0.514 (0.246, 3.926)	2.013 (0.361, 4.928)	0.379 (0.281, 0.928)
$\overline{\Delta F}$	0.274	0.210 (0.123, 0.464)	0.308 (0.131, 0.457)	0.156 (0.113, 0.268)
$B^{sp}_{2009} / B^{target}$	1.000	0.745 (0.000, 3.586)	0.012 (0.000, 2.265)	1.612 (0.161, 2.351)
$\min B^{sp}_{y} / B^{target}$	0.519	0.700 (0.000, 2.456)	0.006 (0.000, 1.832)	1.364 (0.161, 2.389)

Table 6b: As for Table 6a, but here projecting with a 2-line stock-recruit relationship.

Sole: Subarea IV		Beverton-Holt stock recruit relationship with h=0.9		
	Observed catches	**Constant catch** $TAC^{target} = 19570$ Median constant catch required to reach target for each simulation: 23136 (19570, 27311)	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.45$ $p = 3$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2 I^{ave}$ $I^{target} = 1.5 I^{ave}$ $TAC^{target} = 24000$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	19570 (19570, 19570)	20942 (18706, 23266)	20747 (18755, 23163)
$\overline{\Delta TAC}$	0.152	0.006 (0.006, 0.006)	0.069 (0.051, 0.093)	0.045 (0.035, 0.061)
$\overline{F}$	0.908	0.219 (0.160, 0.375)	0.295 (0.230, 0.420)	0.284 (0.228, 0.385)
$\overline{\Delta F}$	0.274	0.149 (0.110, 0.204)	0.142 (0.102, 0.192)	0.146 (0.109, 0.190)
$B^{sp}_{2009} / B^{target}$	1.000	3.369 (1.000, 6.342)	2.331 (0.988, 4.359)	2.611 (1.094, 4.576)
$\min B^{sp}_y / B^{target}$	0.519	2.456 (0.967, 2.456)	1.921 (0.940, 2.456)	2.150 (1.033, 2.456)

Table 7a: Comparison of results for stochastic “forecast” projections for Sole in Subarea IV under a Beverton-Holt stock-recruit relationship for the best performing ”forecast” MPs when incorporating only the BTS-Isis aggregated index in the HCR with a Beverton_Holt stock-recruit relationship. Management quantities shown are medians with associated 95% probabilty intervals in parenthesis. 1000 simulations were performed. Units are tons where applicable.

Sole: Subarea IV		2-line stock recruit relationship		
	Observed catches	**Constant catch** $TAC^{target} = 18743$ Median constant catch required to reach target for each simulation: 22118 (18743,26168)	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.48$ $p = 3$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2 I^{ave}$ $I^{target} = 1.5 I^{ave}$ $TAC^{target} = 23500$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	18743 (18743, 18743)	20104 (18109, 22277)	19877 (18177, 21978)
$\overline{\Delta TAC}$	0.152	0.008 (0.008, 0.008)	0.074 (0.054, 0.098)	0.047 (0.036, 0.061)
$\overline{F}$	0.908	0.220 (0.161, 0.367)	0.322 (0.256, 0.423)	0.286 (0.230, 0.383)
$\overline{\Delta F}$	0.274	0.149 (0.110, 0.204)	0.156 (0.106, 0.196)	0.147 (0.110, 0.191)
$B^{sp}_{2009} / B^{target}$	1.000	2.948 (1.000, 5.519)	2.117 (1.002, 3.867)	2.364 (1.067, 4.094)
$\min B^{sp}_y / B^{target}$	0.519	2.456 (0.929, 2.456)	1.778 (0.944, 2.456)	1.980 (1.007, 2.456)

Table 7b: As for Table 7a, but here for a 2-line stock recruit relationship.

Sole: Subarea IV		Beverton-Holt stock recruit relationship with h=0.9		
	Observed catches	**Constant catch** $TAC^{target} = 19570$	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.45$ $p = 3$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2I^{ave}, I^{target} = 1.5I^{ave}$ $TAC^{target} = 24000$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	19570	21681	22219
$\overline{\Delta TAC}$	0.152	0.006	0.100	0.067
$\overline{F}$	0.908	0.262	0.487	0.501
$\overline{\Delta F}$	0.274	0.244	0.297	0.272
$B_{2009}^{sp} / B^{target}$	1.000	3.178	2.240	1.920
$\min B_y^{sp} / B^{target}$	0.519	2.596	1.390	1.284

Table 8a: Comparison of results for deterministic "hindsight" projections for Sole in Subarea IV under a Beverton-Holt stock-recruit relationship when using only the BTS-Isis aggregated index in the "forecast" MPs. Units are tons where applicable.

Sole: Subarea IV		2-line stock recruit relationship		
	Observed catches	**Constant catch** $TAC^{target} = 18743$	**MP slope: BTS-Isis** $x = 110\%, \lambda = 0.48$ $p = 3$ (max 20% ΔTAC)	**MP target: BTS-Isis** $I^0 = 0.2 I^{ave}, I^{target} = 1.5 I^{ave}$ $TAC^{target} = 23500$ $w = 0.5$ (max 20% ΔTAC)
$\overline{TAC}$	22364	18743	20859	21356
$\overline{\Delta TAC}$	0.152	0.008	0.105	0.066
$\overline{F}$	0.908	0.269	0.501	0.508
$\overline{\Delta F}$	0.274	0.241	0.301	0.272
$B^{sp}_{2009} / B^{target}$	1.000	2.444	1.897	1.592
$\min B^{sp}_y / B^{target}$	0.519	2.191	1.323	1.082

Table 8b: As for Table 8a, but here projecting with a 2-line stock-recruit relationship

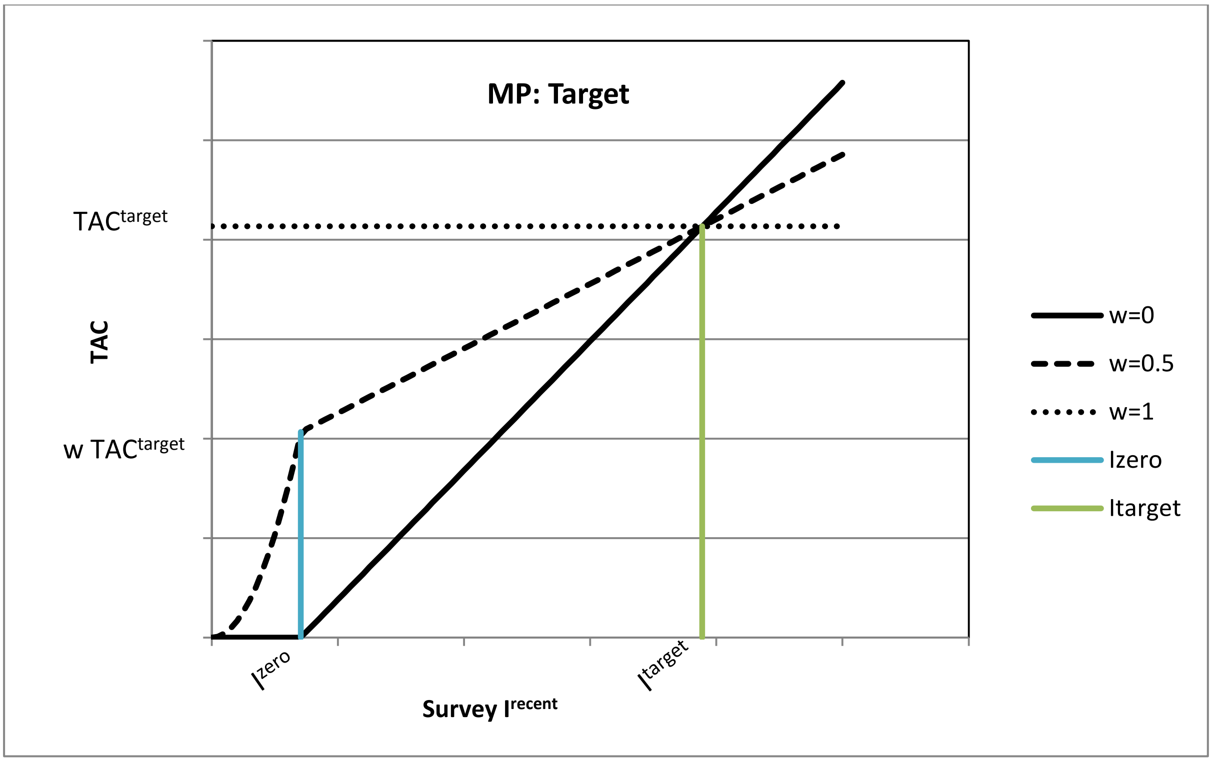


Figure 1: Different target type MPs for three values of *w*: the dashed lines correspond to equations 13, 14 and 16, while the solid black line correspond to equation 15. The vertical lines indicate the zero and target survey values, while the horizontal dotted line corresponds to the target TAC (constant catch rule for *w*=1)

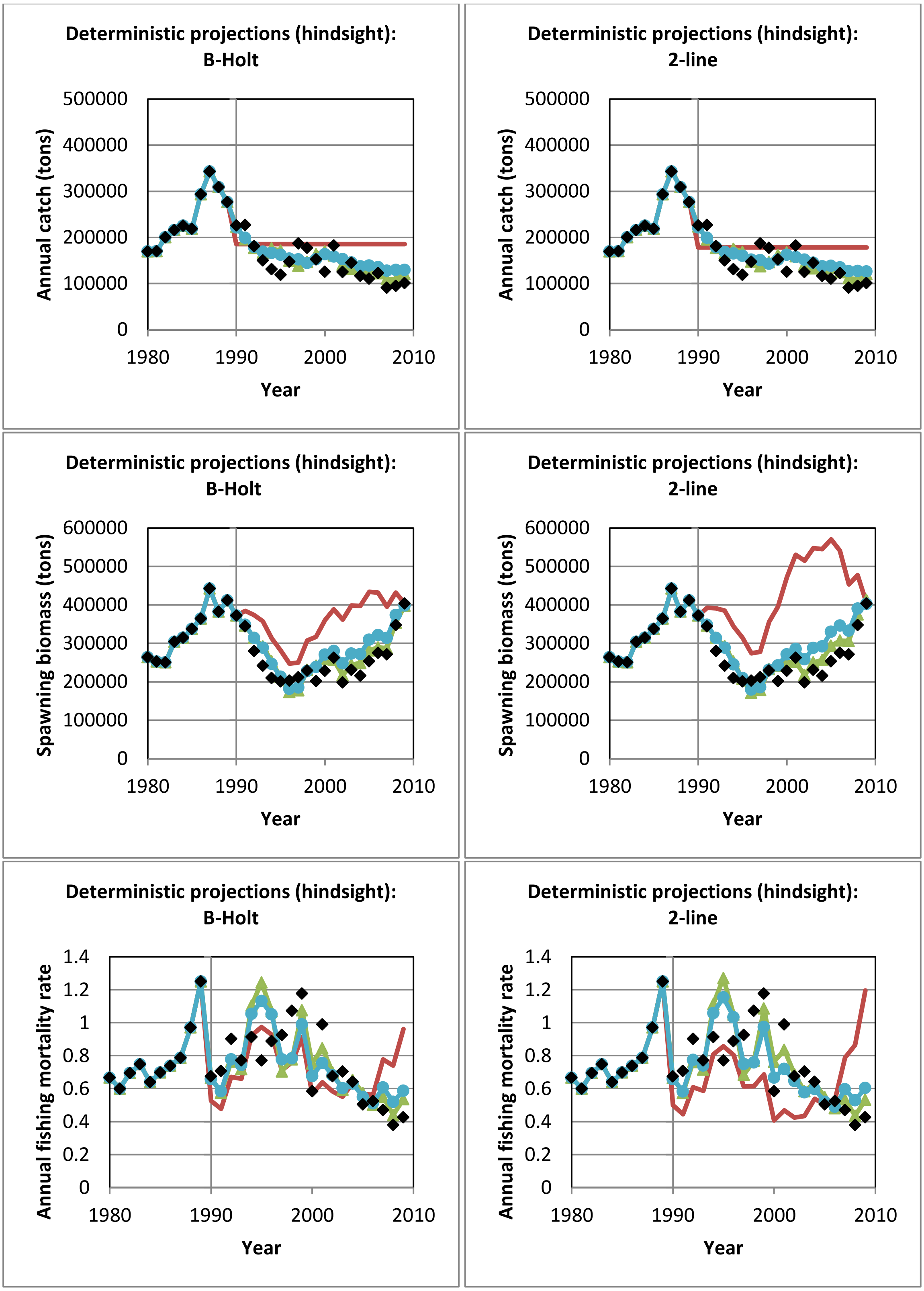
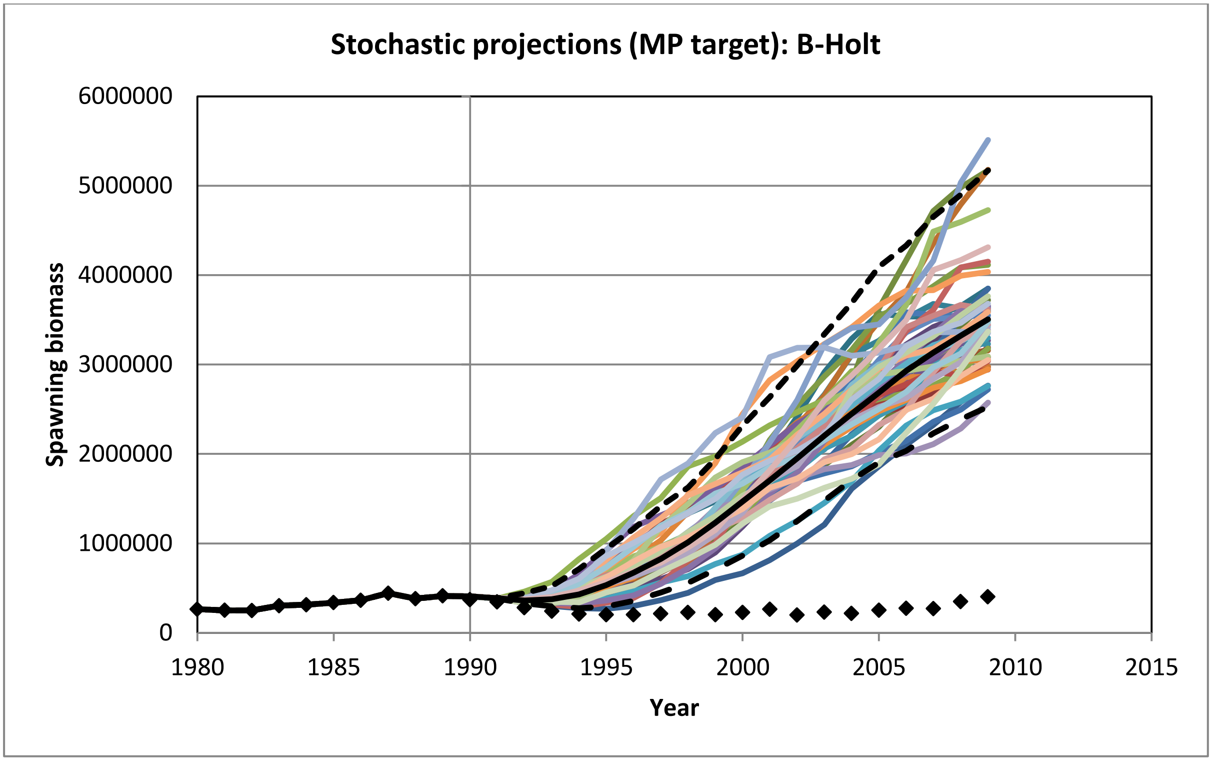


Figure 2: Deterministic "hindsight" projections with either a Beverton-Holt or 2-line stock-recruit relationship from 1990 for a constant catch strategy (line), and for BTS-Isis survey slope (triangles) and target (dots) "hindsight"MPs, compared to the adjusted 2010 XSA assessment estimates for North Sea Plaice (black diamonds). Top plots: total annual catch; middle plots: spawning biomass; bottom plots: annual fishing mortality.



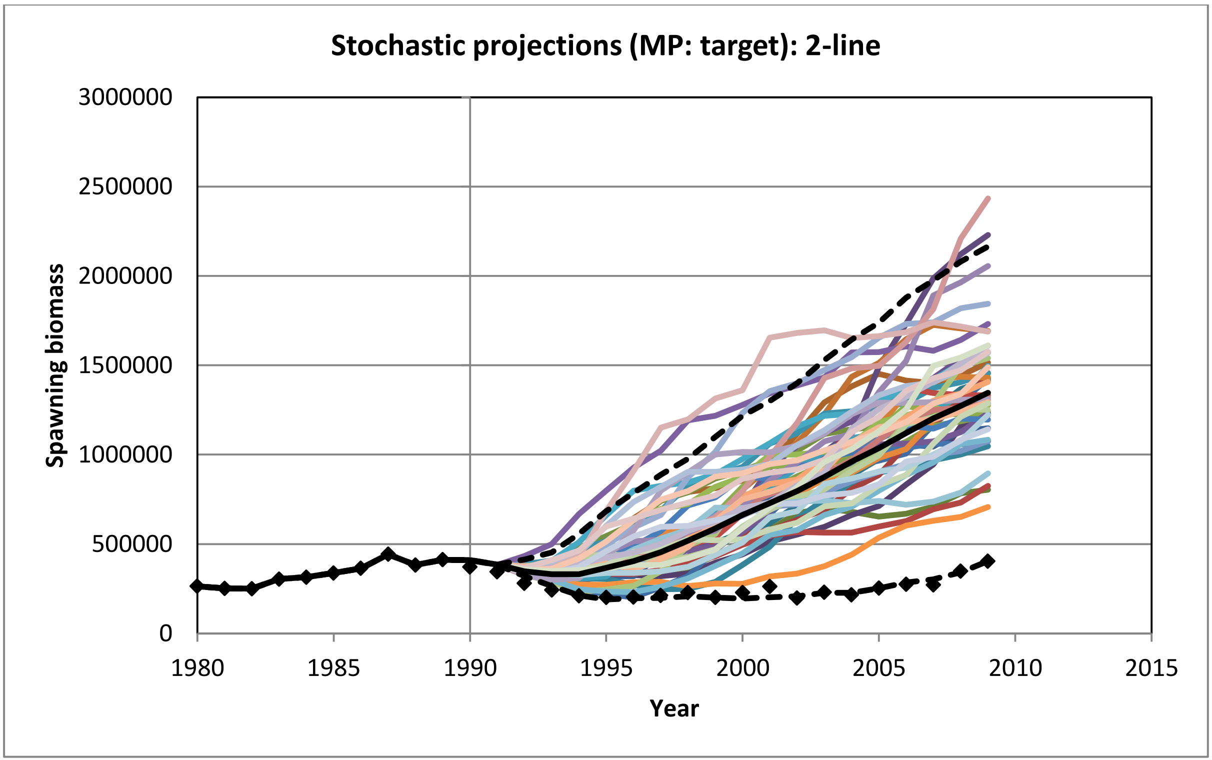
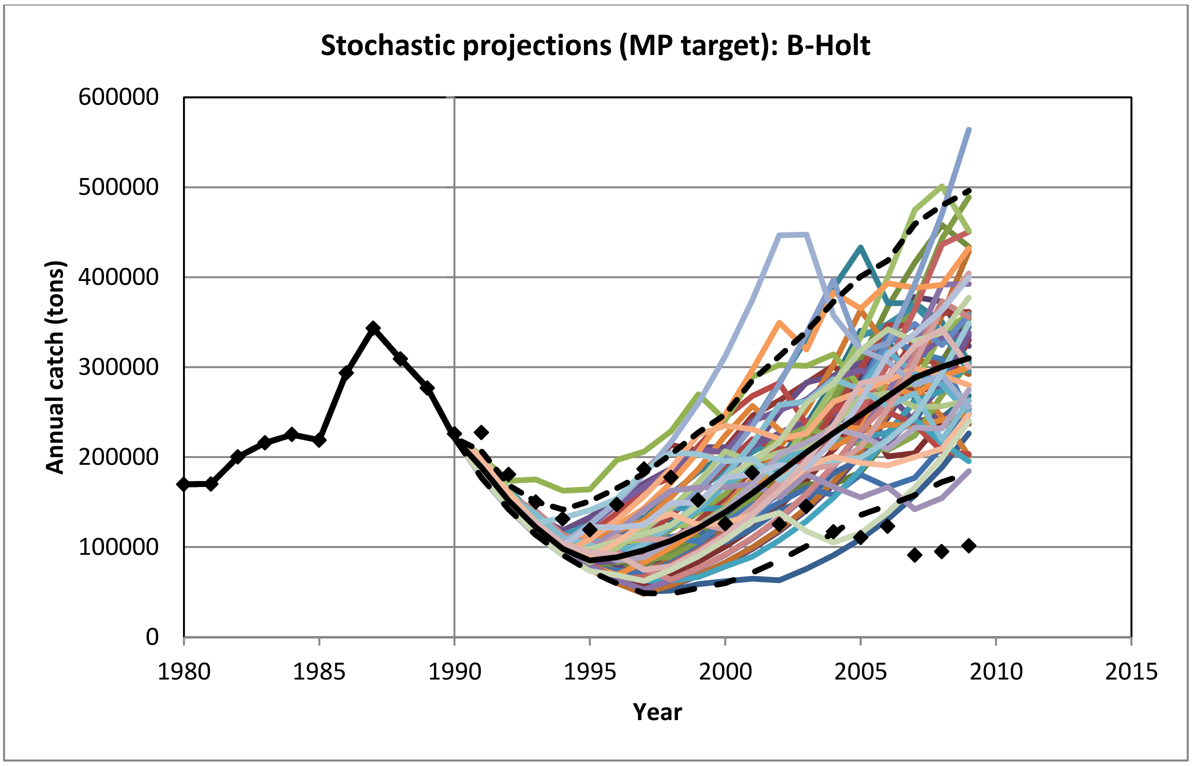


Figure 3: Stochastic "forecast" spawning biomass projections from 1990 for a BTS-Isis survey target "forecast" MP with a Beverton-Holt (top) and a 2-line (bottom) stock-recruit relationship (50 of the 1000 simulations shown here) compared to the adjusted XSA assessment estimates for North Sea Plaice (black diamonds). The medians and 95% PIs are indicated by the solid and dashed black lines.



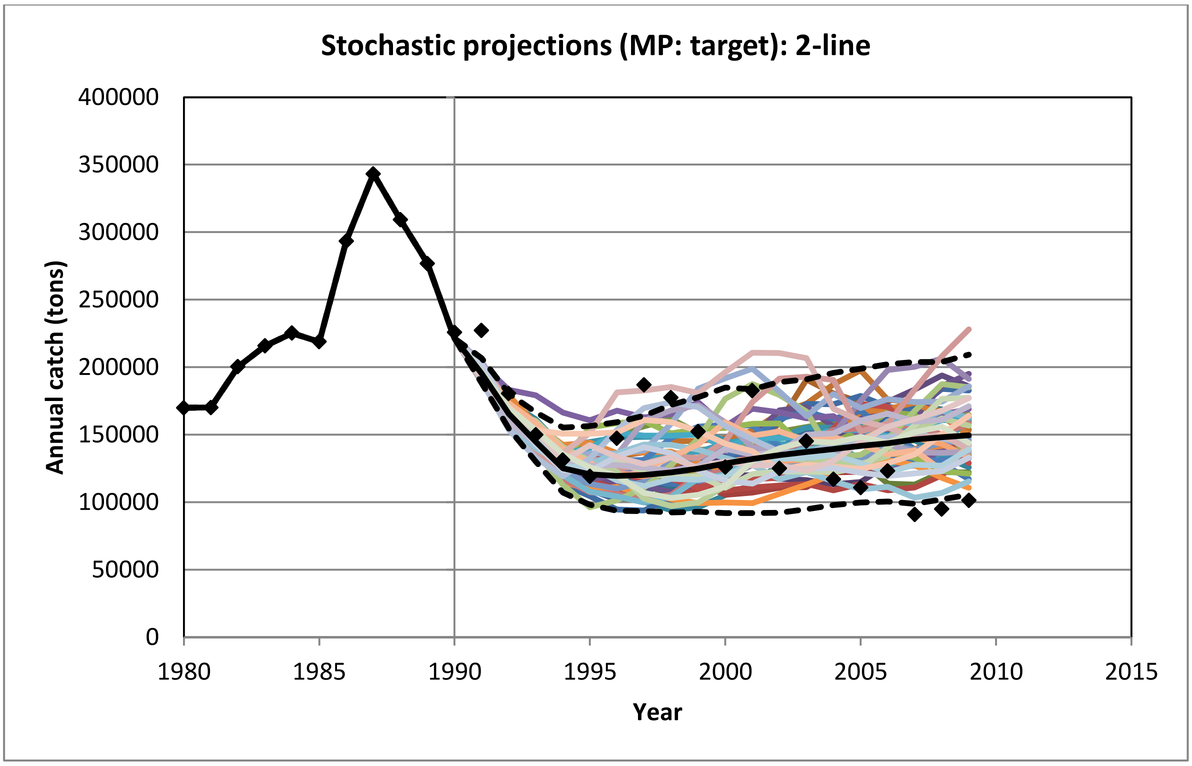


Figure 4: Stochastic "forecast" catch projections from 1990 for a BTS-Isis survey target "forecast" MP with a Beverton-Holt (top) and 2-line (bottom) stock-recruit relationship (50 of the 1000 simulations shown here) compared to the observed catches (landings plus discards) for North Sea Plaice (black diamonds). The medians and 95% PIs are indicated by the solid and dashed black lines.

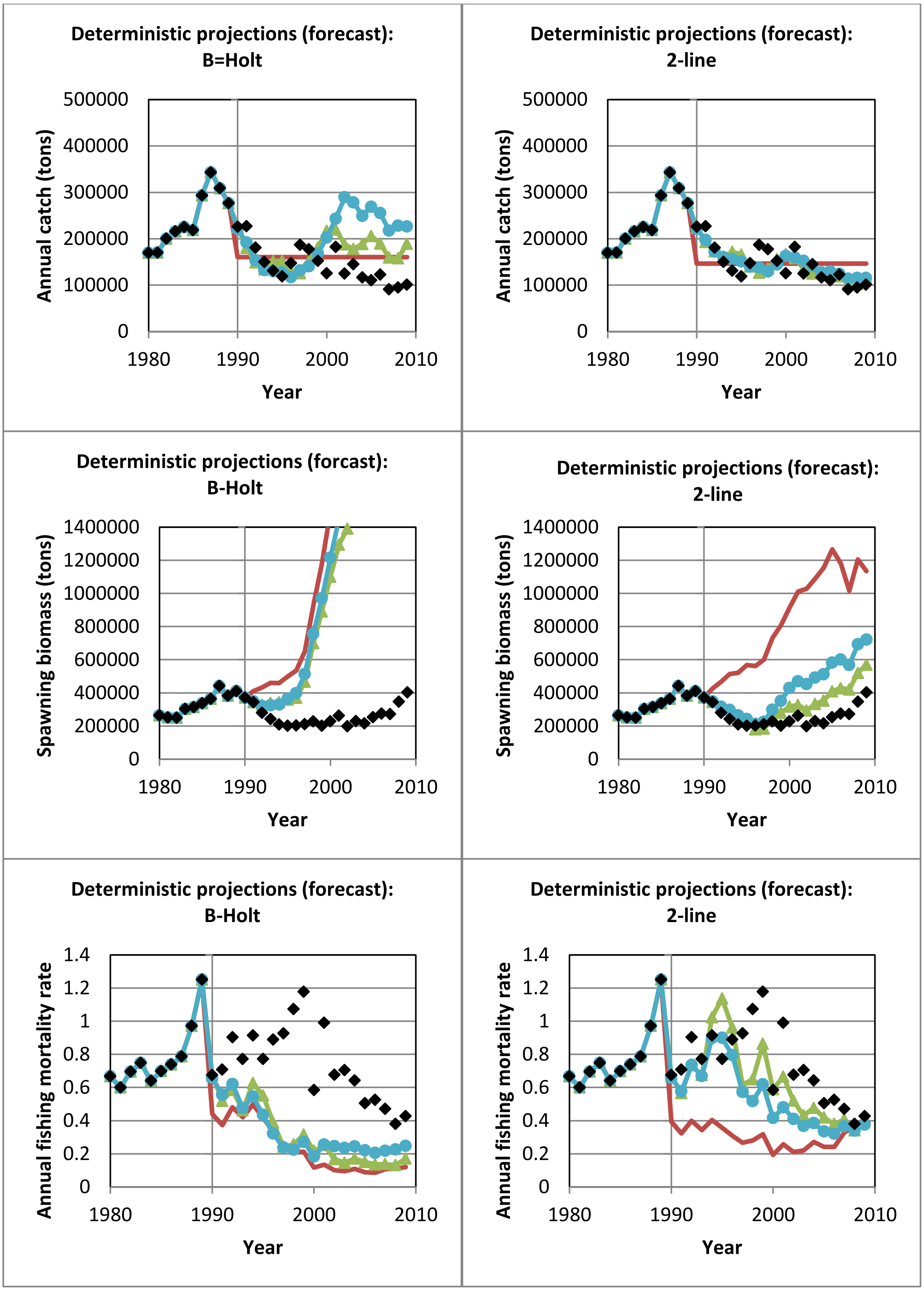


Figure 5: Deterministic "hindsight" projections with a Beverton-Holt (left) and 2-line (right) stock-recruit relationship from 1990 for a constant catch strategy (line), and for BTS-Isis survey slope (triangles) and target (dots) "forecast" MPs, compared to the adjusted 2010 XSA assessment estimates for North Sea Plaice (black diamonds). Top two plots: total annual catch. Middle two plots: spawning biomass. Bottom two plots: annual fishing mortality.

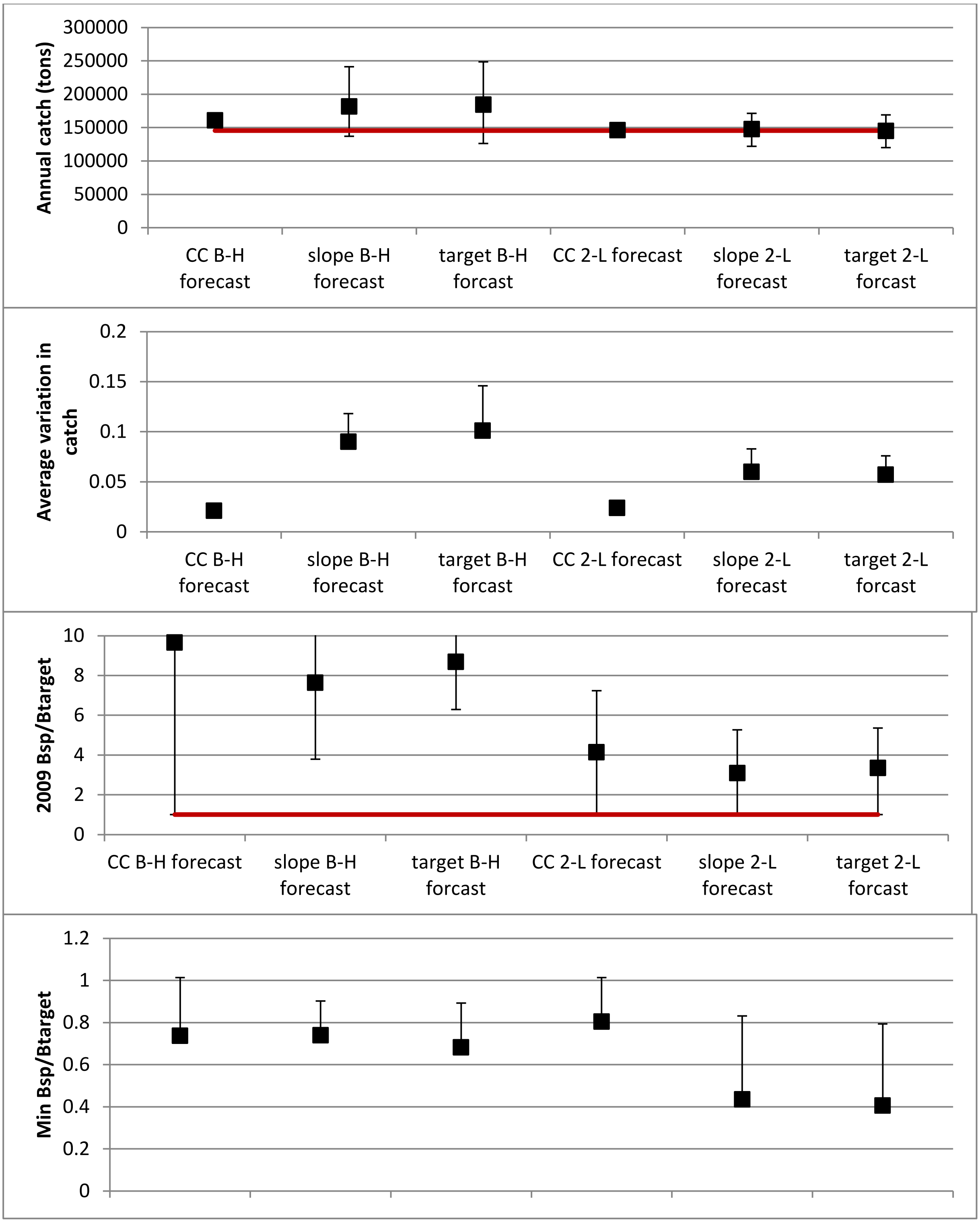


Figure 6a: Comparison of performance statistics for "forecast" MPs for North Sea Plaice over the 1990 to 2009 period when projecting with a Beverton-Holt and 2-line stock-recruit relationship respectively: medians and 95% probability intervals of 1000 simulations. From top to bottom: average annual future catch, average inter-annual variation in catch, final spawning biomass as a fraction of target, and minimum future spawning biomass as a fraction of the target value. The solid horizontal lines indicate results for the adjusted 2010 XSA assessment estimates.

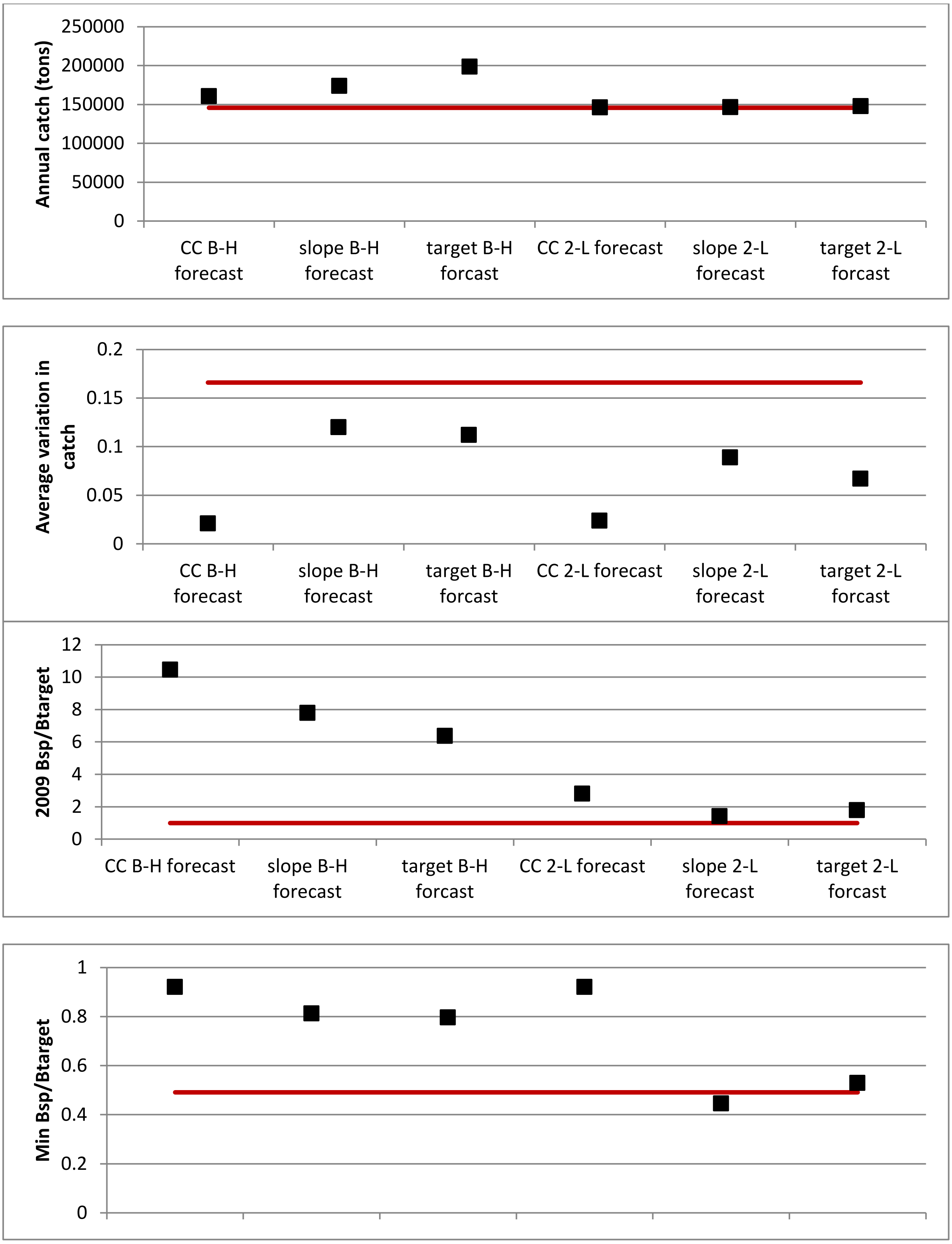


Figure 6b: Comparison of performance statistics for deterministic "hindsight" projections under "forecast" MPs for North Sea Plaice over the 1990 to 2009 period with a Beverton-Holt and 2-line stock-recruit relationship respectively. From top to bottom: average annual future catch, average inter-annual variation in catch, final spawning biomass as a fraction of target, and minimum future spawning biomass as a fraction of the target value. The solid horizontal lines indicate results for the adjusted 2010 XSA assessment estimates.

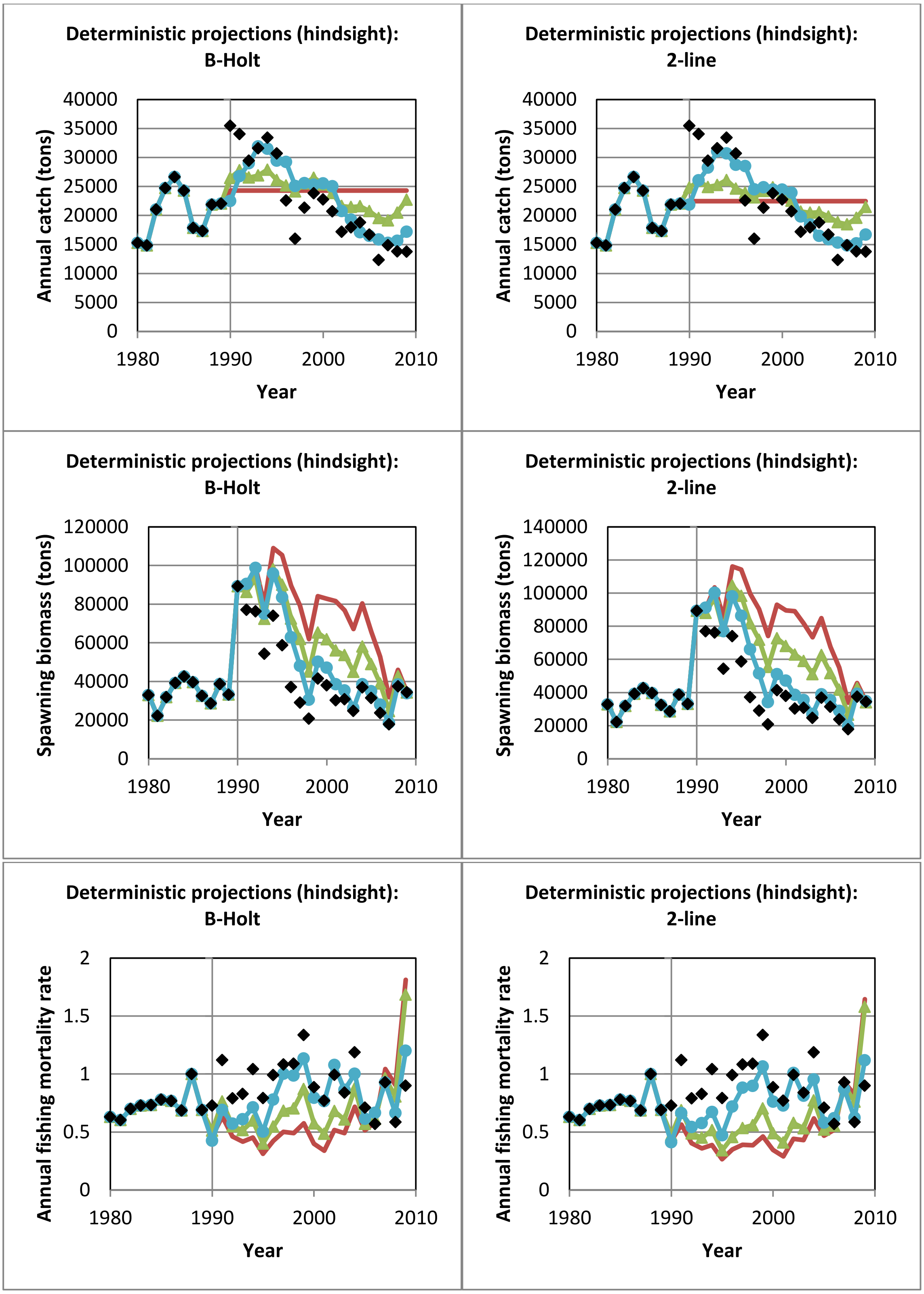
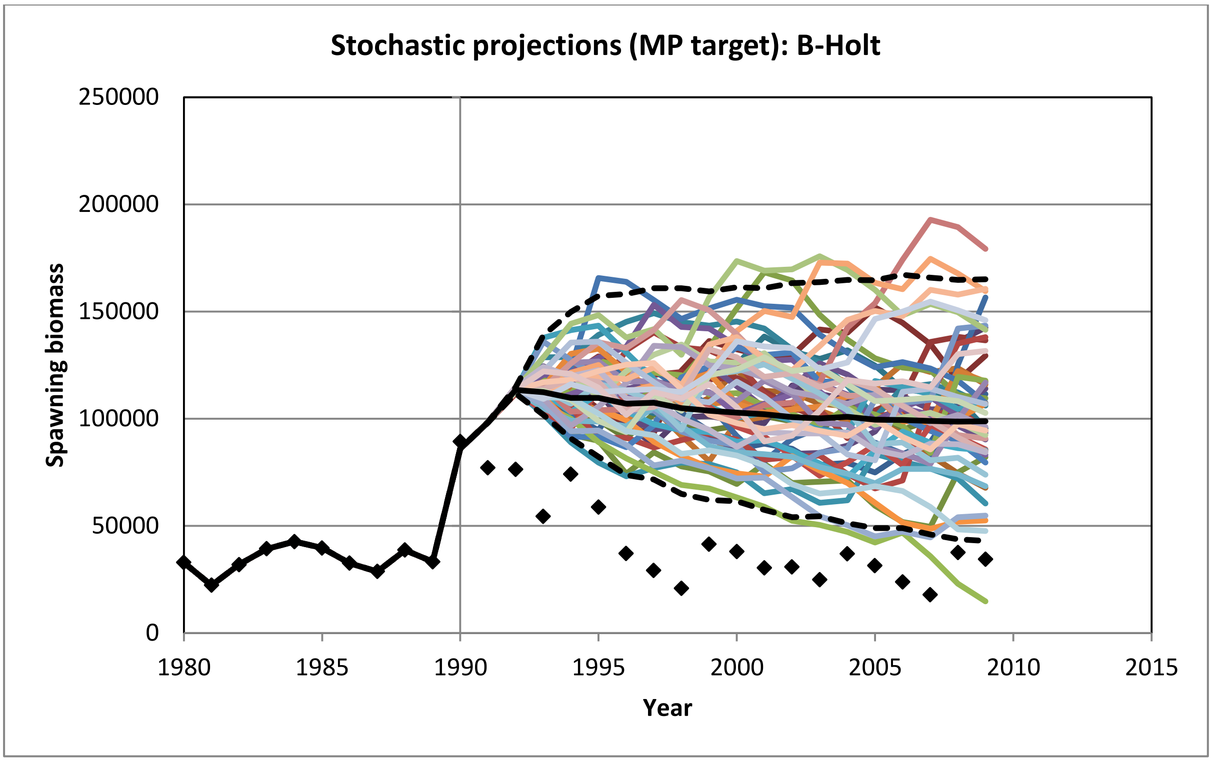


Figure 7: Deterministic "hindsight" projections with either a Beverton-Holt or 2-line stock-recruit relationship from 1990 for a constant catch strategy (line), and for BTS-Isis survey slope (triangles) and target (dots) "hindsight" MPs, compared to the adjusted 2010 XSA assessment estimates for Sole caught in Subarea IV (black diamonds). Top plots: total annual catch; middle plots: spawning biomass; bottom plots: annual fishing mortality.



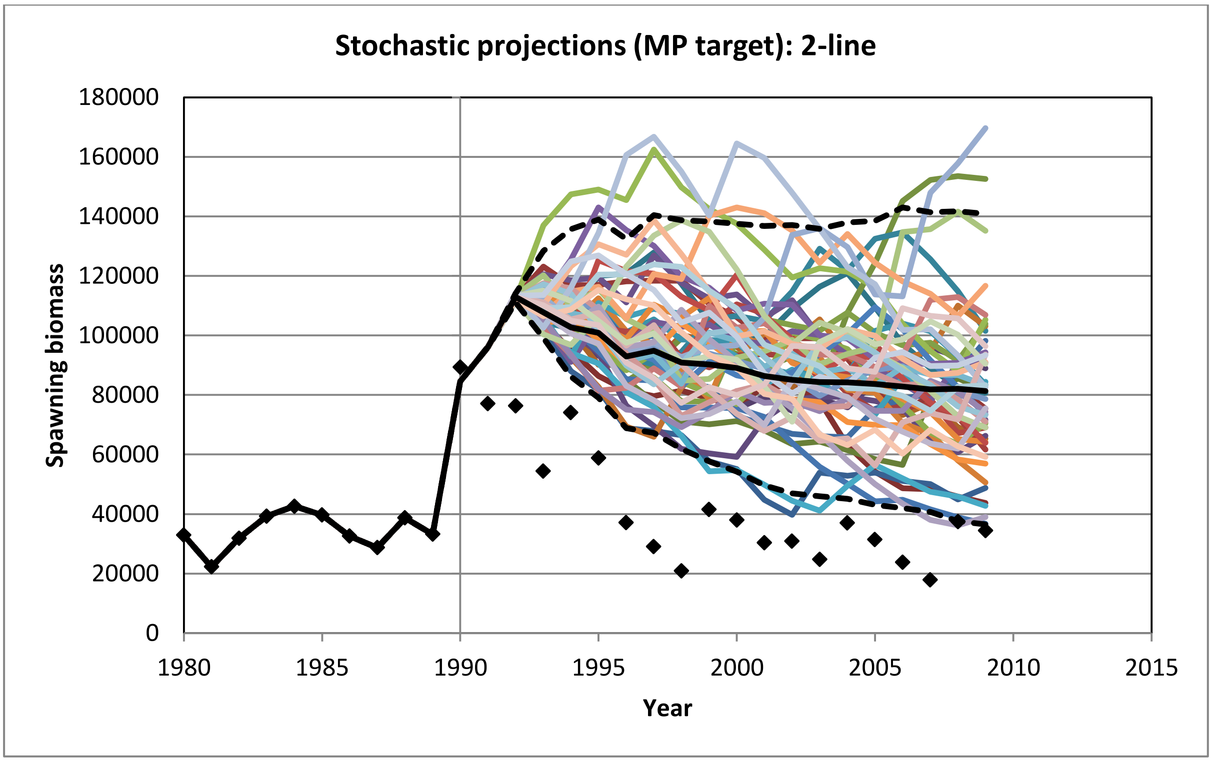
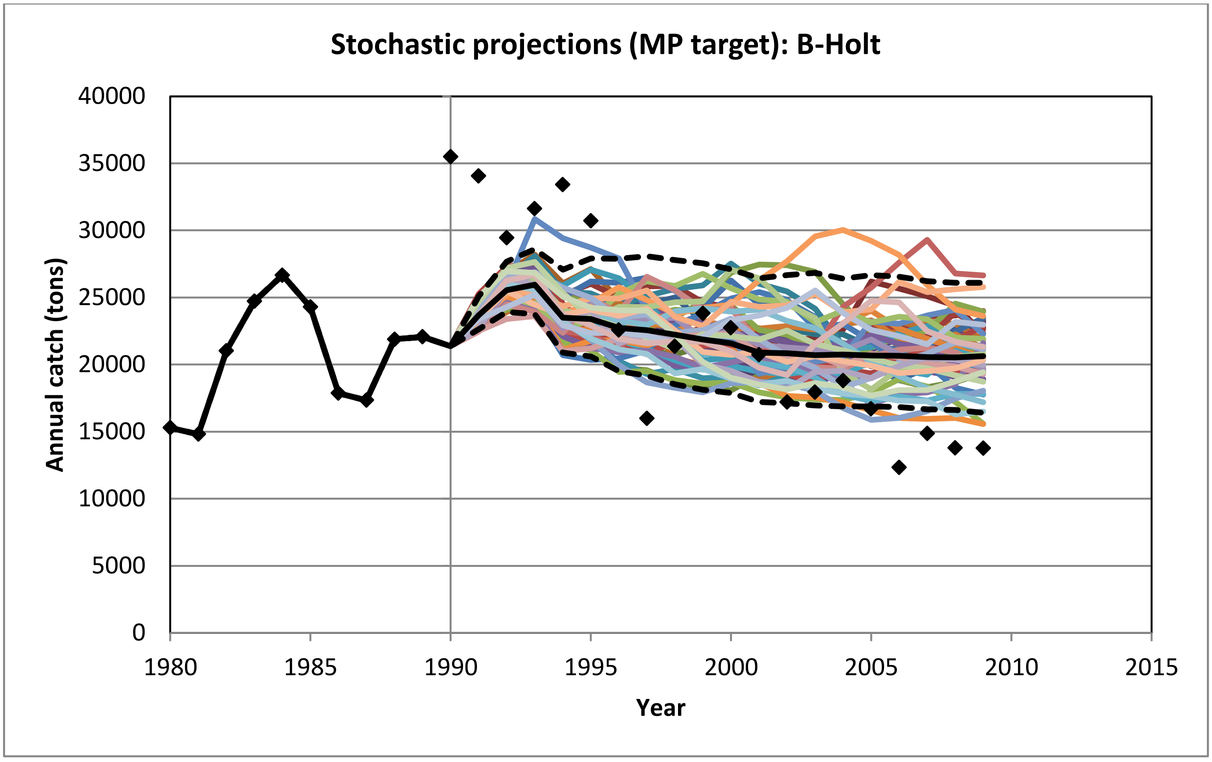


Figure 8: Stochastic "forecast" spawning biomass projections from 1990 for a BTS-Isis survey target "forecast" MPwith a Beverton-Holt (top) and a 2-line (bottom) stock-recruit relationship (50 of the 1000 simulations shown here) compared to the adjusted XSA assessment estimates for Sole in Subarea IV (black diamonds). The medians and 95% PIs are indicated by the solid and dashed black lines.



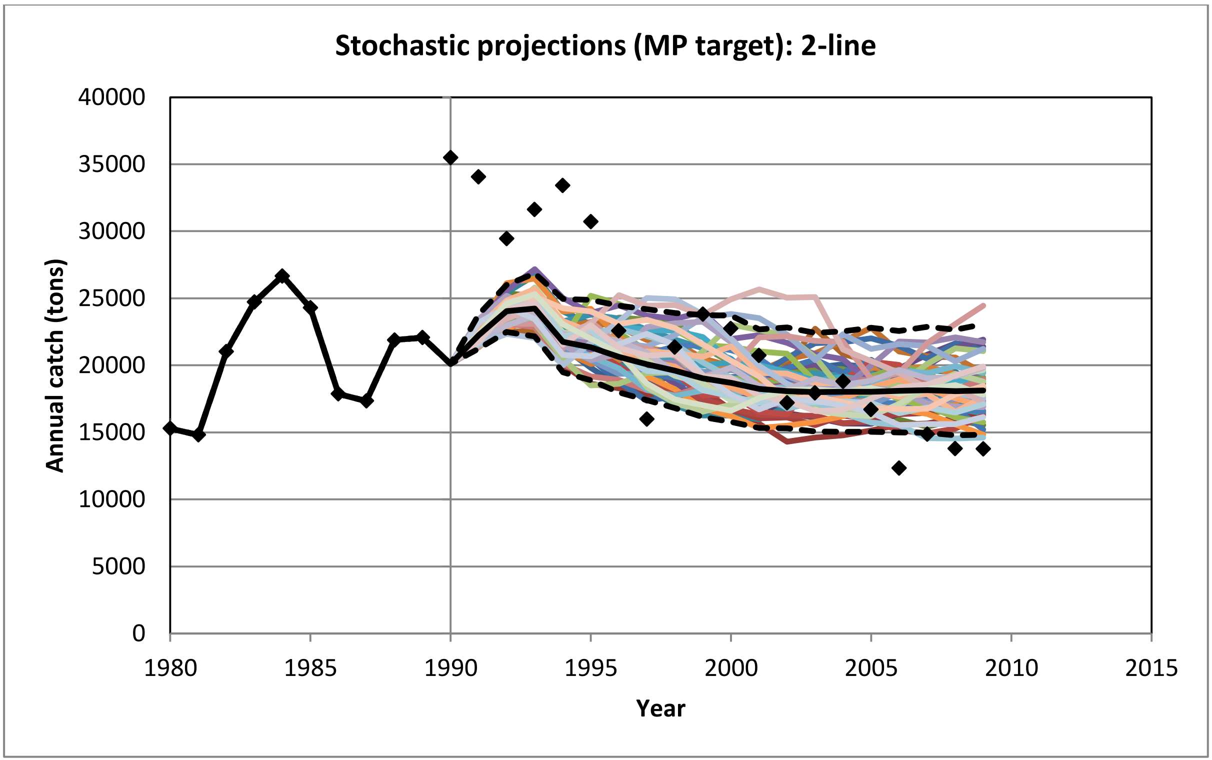


Figure 9: Stochastic “forecast” catch projections from 1990 for a BTS-Isis survey target “forecast” MP with a Beverton-Holt (top) and 2-line (bottom) stock-recruit relationship (50 of the 1000 simulations shown here) compared to the observed catches (landings plus discards) for Sole in Subarea IV (black diamonds). The medians and 95% PIs are indicated by the solid and dashed black lines.

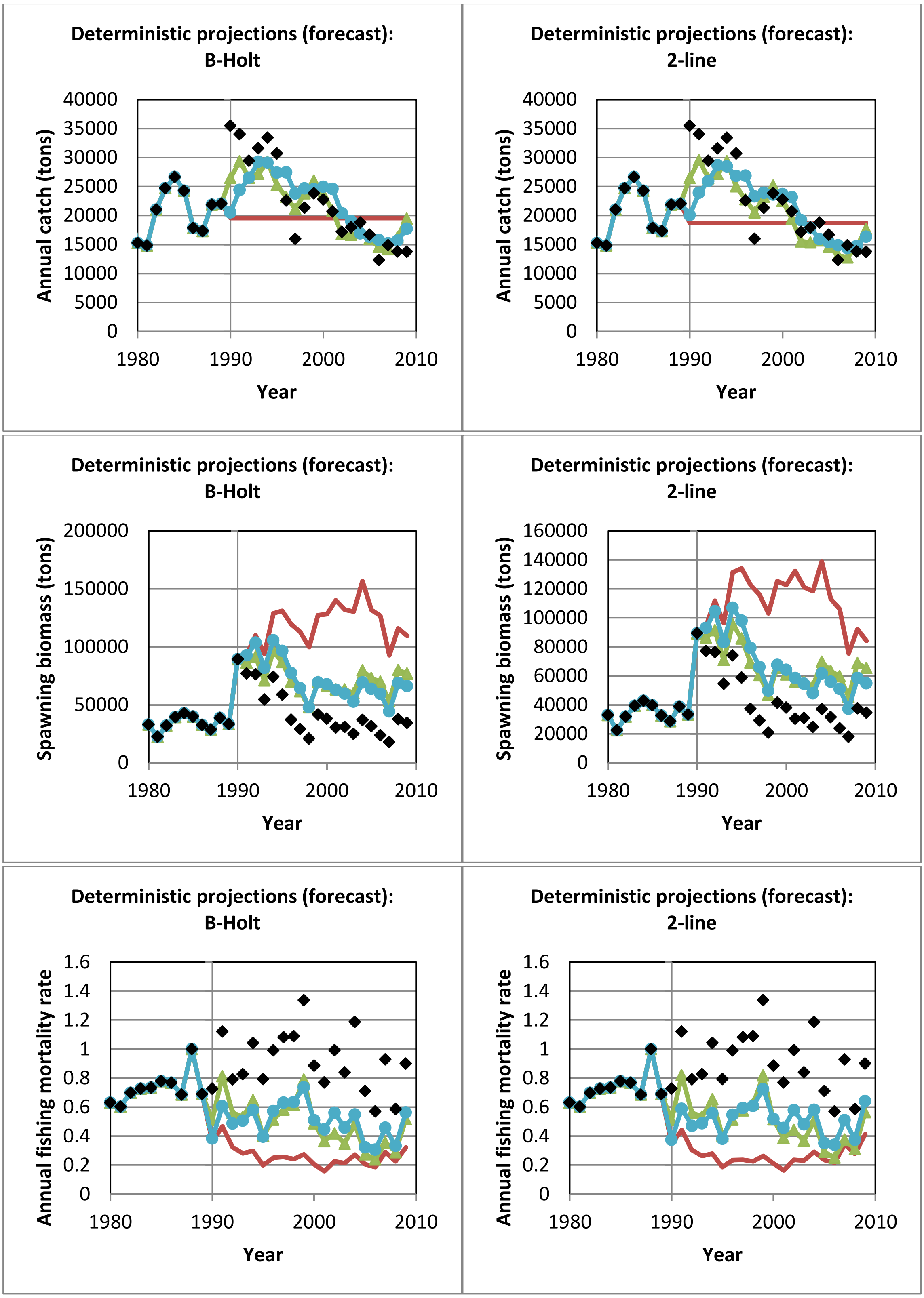


Figure 10: Deterministic "hindsight" projections with a Beverton-Holt (left) and 2-line (right) stock-recruit relationship from 1990 for a constant catch strategy (line), and for BTS-Isis survey slope (triangles) and target (dots) "forecast" MPs compared to the adjusted 2010 XSA assessment estimates for Sole in Subarea IV (black diamonds). Top two plots: total annual catch. Middle two plots: spawning biomass. Bottom two plots: annual fishing mortality.

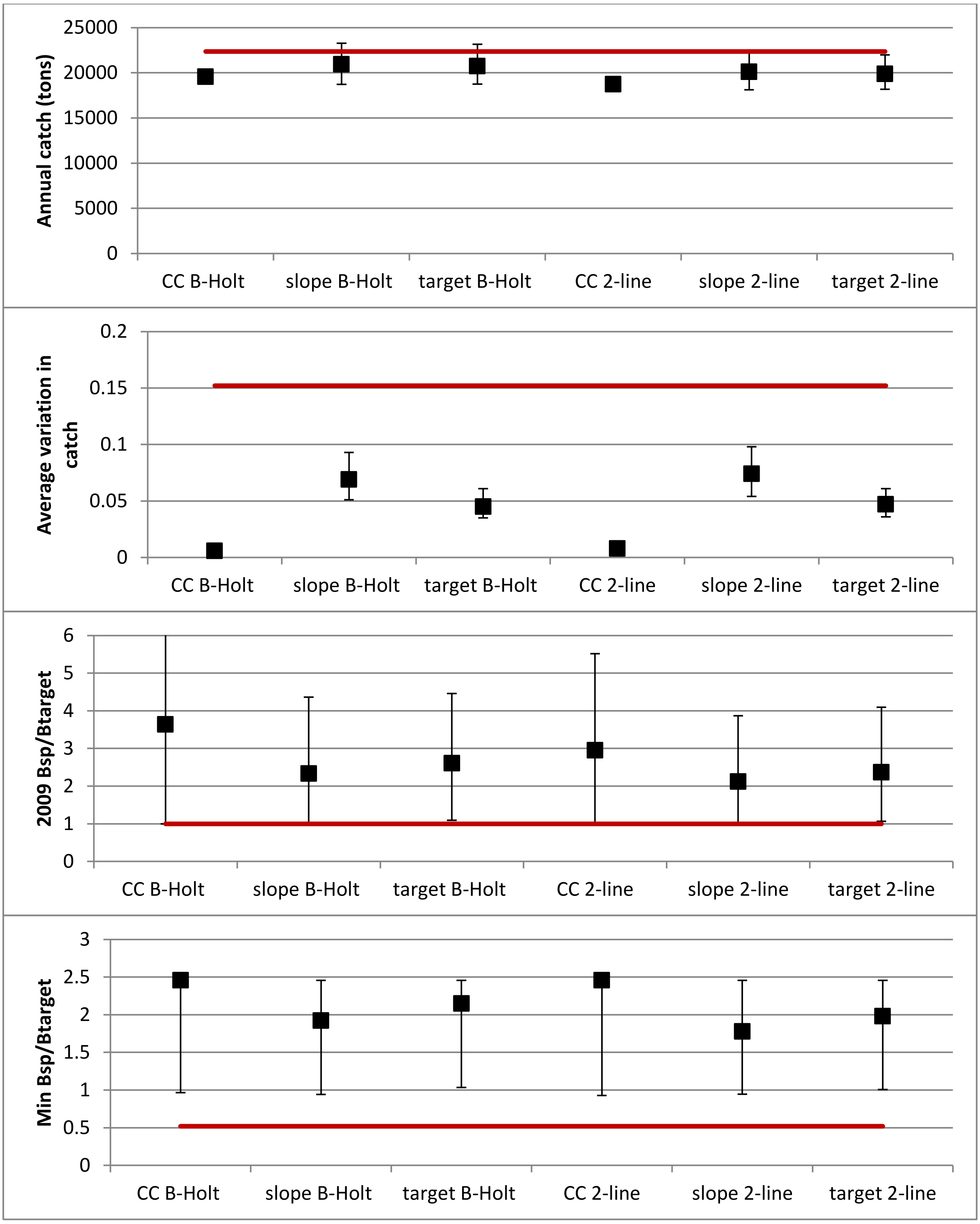


Figure 11a: Comparison of performance statistics for the "forecast" MPs for Sole in Subarea IV over the 1990 to 2009 period when projecting with a Beverton-Holt and 2-line stock-recruitment relationship: medians and 95% probability intervals of 1000 simulations. From top to bottom: average annual future catch, average inter-annual variation in catch, final spawning biomass as a fraction of target, and minimum future spawning biomass as a fraction of the target value. The solid horizontal lines indicate results for the adjusted 2010 XSA assessment estimates.

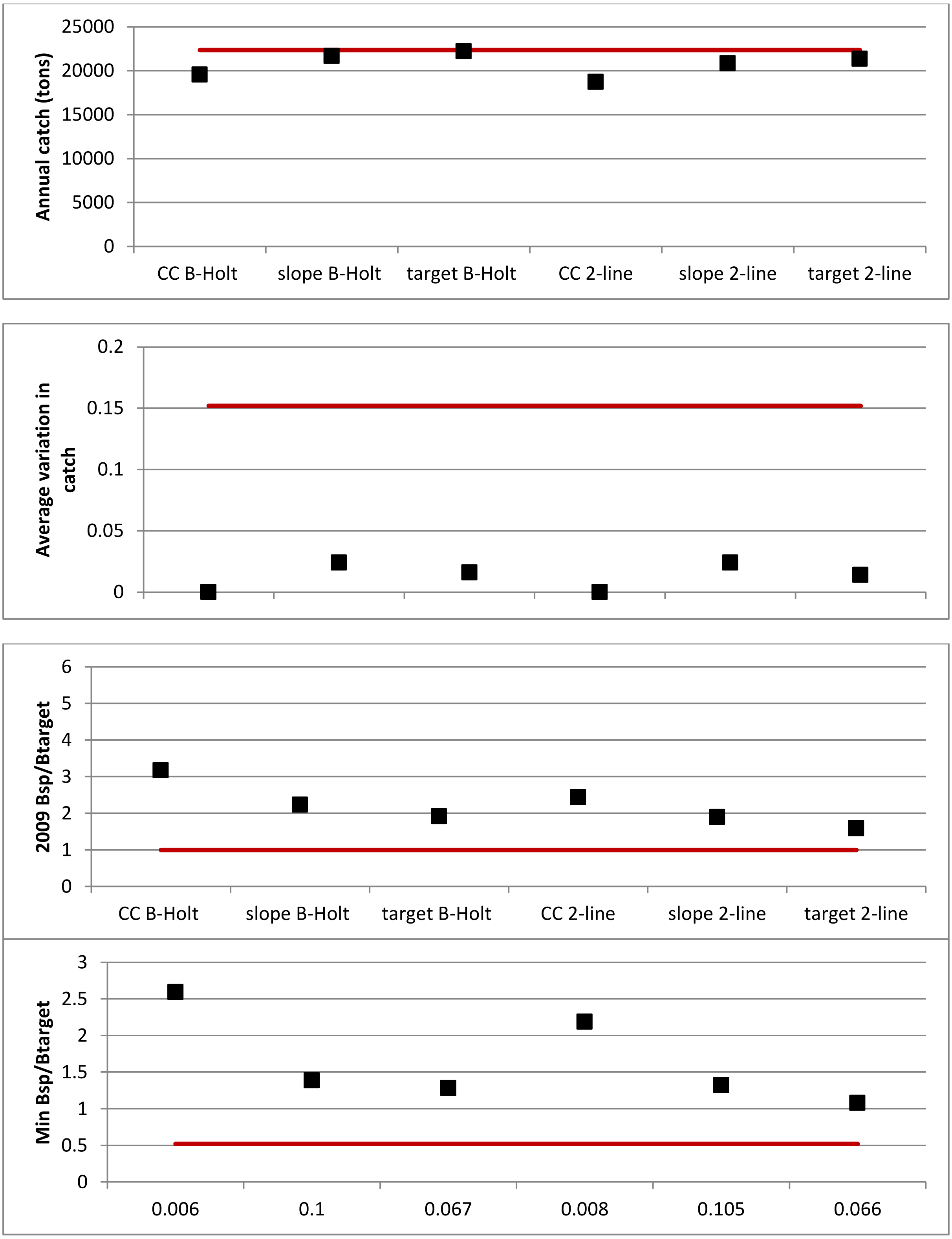


Figure 11b: Comparison of performance statistics for deterministic ("hindsight") projections under "forecast" MPs for Sole in Subarea IV over the 1990 to 2009 period with a Beverton-Holt and 2-line stock-recruitment relationship. From top to bottom: average annual future catch, average inter-annual variation in catch, final spawning biomass as a fraction of target, and minimum future spawning biomass as a fraction of the target value. The solid horizontal lines indicate results for the adjusted 2010 XSA assessment estimates.

Appendix A:

Input to projections

For purposes of this exercise, the 2010 ICES assessment outputs (ICES WGNSSK Report 2010) were used as the starting points from which the projections are performed.

The natural mortality rate and maturity ogive used in the 2010 XSA assessments, and as assumed here for the retrospective projections commencing in 1990, are given in Tables A1.1 and A2.1 for the North Sea Plaice and Sole stocks (subarea IV) respectively.

The annual catches for each of these stocks, the 2010 XSA estimated number of recruits (1-yr-olds) and the associated spawning biomasses are given in Tables A1.3 and A2.3 respectively. The corresponding plots of total annual catches of North Sea Plaice and Sole in Subarea IV are shown in Figures A1.1 and A2.1, while the plots for different biomass components are given in Figures A1.5 and A2.5 respectively.

Plusgroup

The "historic" population numbers and fishing mortalities-at-age for North Sea Plaice and Sole (subarea IV) from 1957 to 1989 are taken from the XSA assessment and are assumed to be known exactly. However, difficulties arise from the manner in which the plusgroup was treated in 2010 assessments which, although this makes little difference to the overall assessment results, in mathematically inconsistent in not respecting equation (A.1) below for the dynamics. Because of the need for comparable consistent reflection of the dynamics in the alternative projections considered in this analysis, the plusgroup numbers and fishing mortalities needed to be re-estimated for the assessment in a way that avoided this inconsistency. Thus, for the sake of consistency between the XSA assessment estimates and the projections, the plusgroup numbers, $N_{y,10}$, were re-estimated such that:

$$N_{y+1,m} = \sum_{a=m-1}^{m} N_{y,a} e^{-Z_{y,a}} \qquad \text{(A.1)}$$

where

$N_{y+1,m}$ is the plusgroup number of fish ($m = 10$) at the start of year *y+1*, and

$Z_{y,a} = M_{y,a} + F'_{y,a}$ is the total mortality on fish in year *y*, where

$M_{y,a}$ is the natural mortality rate, assumed to be age and year-independent, and

$F'_{y,a} = S_{y,a}F_y$ are the fishing mortalities-at-age in year *y*.

In the above equation both $N_{y,m-1}$ and $Z_{y,m-1}$ are known from the XSA assessment. In order to re-compute the plusgroup numbers for the next year, the plusgroup number for year $y-1$ needs to be known, which in turn is computed from the previous year's plusgroup number, etc. Therefore, only an estimate of the first plusgroup, $N_{1,m}$, is required to be able to compute all subsequent plusgroup numbers.

The plusgroup fishing mortality rates, $F_{y,10}$, were re-estimated using the Baranov catch equation:

$$C_{y,m} = F'_{y,m} N_{y,m} (1 - e^{-Z_m}) / Z_m \tag{A.2}$$

In addition, flat fishing selectivity was assumed at older ages so that:

$$F'_{y,m} = F'_{y,m-1} \tag{A.3}$$

Since the above equations cannot be satisfied simultaneously, $N_{1,m}$ and $F_{y,10}$ were estimated in terms of their maximum likelihood values. The likelihood is calculated assuming that the observed plusgroup catches defined by equation (A.2) are log-normally distributed about their true values:

$$C_{y,m} = C_{y,m} e^{\zeta_y} \tag{A.4}$$

where $\zeta_y \sim N(0, (\sigma^C)^2)$. Similarly, the plusgroup fishing mortalities are assumed to be log-normally distributed about their expected values:

$$F'_{y,m} = F'_{y,m-1} e^{\tau_y} \tag{A.5}$$

where $\tau_y \sim N(0, (\sigma^F)^2)$.

The contributions to the negative of the (penalised) log-likelihood function are given by:

$$-\ln L = -\ln L^F - \ln L^C \qquad \text{(A.6)}$$

where

$$-\ln L^F = \sum_y [\ln \sigma^F + (\ln F'_{y,m-1} - \ln F'_{y,m})^2 / 2(\sigma^F)^2] \qquad \text{(A.7)}$$

and

$$-\ln L^C = \sum_y [\ln\sigma^C + (\ln C_{y,m} - \ln C_{y,m})^2 / 2(\sigma^C)^2] \qquad \text{(A.8)}$$

where σ^F and σ^C are the standard deviation of the residuals, estimated in the fitting procedure by their maximum likelihood values

$$\sigma^F = \sqrt{1/n \sum_y (\ln F'_{y,m} - \ln F'_{y,m-1})^2} \qquad \text{(A.9)}$$

and

$$\sigma^C = \sqrt{1/n \sum_y (\ln C_{y,m} - \ln C_{y,m})^2} \qquad \text{(A.10)}$$

where *n* is the number of years over which the summation is taken.

The adjusted population numbers and fishing mortality matrices, $N_{y,a}$ and $F'_{y,a}$, are given in Tables A1.4 and A1.5 for North Sea Plaice, and Tables A2.4 and A2.5 for Sole in Subarea IV. Due to the near-zero estimates of σ^F, the $F'_{y,a}$ matrices remain effectively unchanged from those estimated in the 2010 ICES assessments. The plots of the adjusted plusgroup population numbers, $N_{y,10}$, and annual plusgroup catches (landings and discards), $C_{y,10}$, are shown in Figures A1.2 and A1.3 for North Sea Plaice, and Figures A2.2 and A2.3 for Sole in subarea IV.

The catch and population weights-at-age matrices, $w^C_{y,a}$ and $w^S_{y,a}$ were taken directly from those used in the 2010 XSA assessments, shown in Figures A1.13 and A1.14 for North Sea Plaice and A2.11 and A2.12 for Sole in Subarea IV. Decreasing trends in weights at older ages are clearly visible in these plots since 1990 for both Plaice and Sole stocks.

The age- and year-dependent fishing selectivities were derived from the adjusted $F'_{y,a}$ matrix such that

$$S_{y,a} = F'_{y,a} / F_y \tag{A.11}$$

where $F_y = \max_a (F'_{y,a})$.

The annual fishing selectivity-at-age vectors are shown in Figures A1.7 to A1.10 for North Sea Plaice, and Figures A2.7 and A2.8 for Sole caught in subarea IV.

Stock-recruitment relationship

The number of recruits is assumed to be log-normally distributed about a stock-recruitment relationship such that

$$R_y^{XSA} = R_y e^{\varsigma_y} \tag{A.12}$$

where

R_y^{XSA} are the number of recruits in year y, input from the 2010 XSA assessment,

R_y is the number of recruits according to some stock-recruit relationship, and

ς_y are the corresponding recruitment residuals.

The objective function minimized to estimate the parameters of the relationship is given by

$$-\ln L = \sum_y [\ln \sigma^R + (\ln R_y^{XSA} - \ln(R_y)) / 2(\sigma^R)^2] \tag{A.13}$$

where $\sigma^R = \sqrt{1/n \sum_y (\ln R_y^{XSA} - \ln R_y)^2}$ is the standard deviation of the residuals estimated in the fitting procedure by its maximum likelihood value and y runs over the “historic” years from 1957 to 1989 for the stochastic (“forecast”) projections, and from 1957 to 2009 for the deterministic (“hindsight”) projections.

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Two forms of relationships are considered.

Beverton-Holt:

The number of recruits is given by a Beverton-Holt stock-recruitment relationship such that

$$R_y = \frac{\alpha B_{y-1}^{sp}}{\beta + B_{y-1}^{sp}} \tag{A14}$$

where

B^{sp}_{y-1} is the spawning biomass in year $y-1$, corresponding to the adjusted 2010 XSA assessment estimates, and

α and β are the stock-recruitment parameters which are estimated.

Note: The "steepness" of the stock-recruitment curves (recruitment at $B^{sp} = 0.2K$ as a fraction of recruitment at $B^{sp} = K$) was estimated to be close to one, i.e., $\beta = 0$ and hence effectively constant recruitment regardless of the level of spawning biomass. This is frequently criticized as there is negligible penalty if harvests reduce the resource to very low levels. Therefore, the steepness parameter, *h*, was fixed to 0.9 when estimating α, with β given in terms of *h* such that

$$\beta = \alpha(SBR)(1-h)/4h \qquad \text{(A.15)}$$

where SBR is the pre-exploitation spawning biomass per recruit.

Plots of the number of recruits obtained from the XSA assessment, along with the corresponding Beverton-Holt estimates, are shown in Figures A1.6 and A1.7 for Plaice and A2.6 and A2.7 for Sole respectively.

*2-Line***:**

Due to the unrealistically high estimates of *h* for the Beverton-Holt relationship ($h = 0.98$ for North Sea Plaice and $h = 1$ for Sole in Subarea IV), an alternative stock-recruit relation was tested: a two line (or "hockey-stick") stock-recruit function, where the expected number of recruits is constant above a certain spawning biomass level, and as the spawning biomass falls below that level, the number of recruits decreases linearly to zero. The level chosen is the minimum spawning biomass (B^0) in the time series from the (adjusted) XSA assessment.

The number of recruits, R_y, is given by

$$\begin{aligned} B^{sp}_{y-1} < B^0 : \quad & R_y = (\alpha B^{sp}_{y-1} / B^0) e^{\zeta_y} \\ B^{sp}_{y-1} \geq B^0 : \quad & R_y = \alpha e^{\zeta_y} \end{aligned} \qquad \text{(A.16)}$$

where

α is the number of recruits (constant) when the spawning biomass is above a pre-specified minimum value,

$B^0 = \min_y(B_y^{XSA})$ denotes the minimum spawning biomass over the period under consideration below which the number of recruits decline linearly.

The stock-recruit parameter estimates obtained by minimizing equation (A.13) are given in Table A1.2 for North Sea Plaice and A2.2 for Sole in Subarea IV.

Survey abundance data

A variety of age-disaggregated survey data was used to tune the XSA assessment. However, for the purposes of this paper an age-aggregated index is required:

$$I_y^i = \sum_a w_{y,a}^S I_{y,a}^i \tag{A.17}$$

where $I_{y,a}^i$ are the age-disaggregated survey indices corresponding to BTS-Isis, BTS-Tridens and SNS for Plaice, and BTS-Isis and SNS for Sole. The abundance indices, I_y^i, are assumed to be log-normally distributed about their expected values such that

$$I_y^i = \hat{I}_y e^{\varepsilon_y^i} \tag{A.18}$$

where

I_y^i is the age-aggregated survey abundance index *i* for year *y* given by equation (A.17),

$\hat{I}_y^i = q^i B_y^{sur\_i}$ is the corresponding model estimate, where

$B_y^{sur\_i}$ is the survey biomass estimate for year y ,

q^i is the constant of proportionality for abundance series *i* given by

$$\ln q^i = 1/n \sum_y (\ln I_y^i - \ln B_y^{sur\_i}) \tag{A.19}$$

and ε_y^i are the residuals

$$\varepsilon_y^i = \ln I_y^i - \ln(q^i B_y^{sur\_i}) \tag{A.20}$$

with the standard deviation of the residuals for survey index *i* given by

$$\sigma^i = \sqrt{1/n(\sum_y \varepsilon_y^i)^2} \tag{A.21}$$

The biomass for year y corresponding to survey index i is given by

$$B_y^{sur\_i} = \sum_{a=1}^{10} S_a^{sur\_i} w_{y,a}^S N_{y,a} \qquad \text{(A.22)}$$

where

$w_{y,a}^S$ denote the population weights-at-age for each year which are input,

$N_{y,a}$ are the adjusted 2010 XSA assessment population numbers-at-age, and

$S_a^{sur\_i}$ is the fishing selectivity vector associated with survey abundance index i given by

$$S_a^{sur\_i} = 1/n \sum_y I_{y,a}^{sur\_i} / N_{y,a} \qquad \text{(A.23)}$$

where

$I_{y,a}^{sur\_i}$ is the age-disaggregated survey data matrix corresponding to index i which is input,

n is the number of years of survey data in index i, and

$N_{y,a}$ corresponds to the 2010 XSA population numbers with adjusted plusgroup.

The age-aggregated survey estimates are given in Tables A1.6 and A2.6 for North Sea Plaice and Sole respectively. The corresponding plots of the survey indices are shown in Figures A1.4 and A2.4.

Section A1: North Sea Plaice (subarea IV)

The natural mortality-at-age and maturity-at-age vectors used in the XSA assessment and retrospective projections from 1990 for North Sea Plaice (subarea IV).

Age	1	2	3	4	5	6	7	8	9	10
Natural mortality rate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Maturity	0	0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table A1.1: Natural mortality-at-age and maturity-at-age vectors.

The stock-recruit parameters estimated for the Beverton-Holt and 2-line functions used in the deterministic and stochastic projections.

		Beverton-Holt		2_line	
	Period	α (thousands)	β (tons)	α (thousands)	B^0 (tons)
Determinstic ("Hindsight")	1957-2009	2301950	434656	927286	198132
Stochastic ("Forecast")	1957-1989	2147080	405408	939615	250267

Table A1.2: Stock-recruit parameters.

Year	Number of recruits	Spawning biomass	Total catch	Landings	Discards
1957	457973	288705	78443	70563	7880
1958	698110	291614	88191	73354	14837
1959	863386	291514	109164	79300	29864
1960	757298	302878	117334	87541	29793
1961	860576	309561	118474	85984	32490
1962	589154	365078	125375	87472	37903
1963	688366	348818	148376	107118	41258
1964	2231500	339871	147571	110540	37031
1965	694573	316015	140223	97143	43080
1966	586777	337571	166552	101834	64718
1967	401295	403512	163365	108819	54546
1968	434277	382406	139521	111534	27987
1969	648869	350206	142820	121651	21169
1970	650576	326437	159982	130342	29640
1971	410270	291251	136939	113944	22995
1972	366617	299224	142475	122843	19632
1973	1312009	252552	143783	130429	13354
1974	1132726	259124	157485	112540	44945
1975	864773	273132	195235	108536	86699
1976	692682	292629	166917	113670	53247
1977	988665	307704	176689	119188	57501
1978	912345	295538	159639	113984	45655
1979	891239	287895	213282	145347	67935
1980	1128156	263884	171031	139951	31080
1981	865944	252209	172778	139747	33031
1982	2031170	250267	203674	154547	49127
1983	1308491	303768	218521	144038	74483
1984	1259358	314454	226963	156147	70816
1985	1848419	337665	220387	159838	60549
1986	4760609	364215	295300	165347	129953
1987	1962845	442388	344194	153670	190524
1988	1770461	382424	310898	154475	156423
1989	1186811	411792	277611	169818	107793
1990	1036516	371947	227465	156240	71225
1991	914585	343770	228939	148004	80935
1992	776744	279797	182239	125190	57049
1993	530684	242006	152129	117113	35016
1994	442947	209421	134177	110392	23785
1995	1164164	201208	120184	98356	21828
1996	1290364	202807	133722	81673	52049
1997	2155842	211554	183193	83048	100145
1998	774928	228808	175285	71534	103751
1999	840878	201461	151638	80662	70976
2000	991191	228618	125459	81148	44311
2001	540350	262660	182272	81963	100309
2002	1726207	198132	124607	70217	54390
2003	537804	230789	144294	66502	77792
2004	1248173	215963	115902	61436	54466
2005	791655	252773	109576	55700	53876
2006	922375	275293	119789	57943	61846
2007	1046417	271502	89179	49744	39435
2008	821795	347508	94749	48874	45875
2009	1017863	403767	100198	54973	45225

Table A1.3: Spawing biomass estimates from the adjusted 2010 XSA assessment, with total annual catches (landings and discards) for North Sea Plaice.

Year	1	2	3	4	5	6	7	8	9	10
1957	457973	256778	322069	182986	117504	49780	48438	35192	20763	58933
1958	698110	383614	184865	225749	122171	75186	36568	33338	23255	53959
1959	863386	568706	270362	123650	142799	76063	49331	25309	22555	50581
1960	757298	670799	377298	171551	76786	85609	46907	31440	16805	45847
1961	860576	614899	441591	239779	105744	48183	50972	28949	19875	38652
1962	589154	706789	416674	283132	151855	63044	31337	32158	16921	36179
1963	688366	484324	465009	259569	172009	89026	37245	19737	20503	32369
1964	2231500	536380	304564	276885	152215	101919	50127	21480	11359	30565
1965	694573	1956330	325547	176043	156783	80258	56631	30309	13162	23972
1966	586777	586899	1355540	198052	105458	99441	43686	33776	19288	22299
1967	401295	494319	371937	832385	116531	59210	63824	23833	20304	24356
1968	434277	343893	314556	224454	500704	65484	32351	42364	13952	26340
1969	648869	322587	233484	201830	141578	314124	42894	19435	28723	25665
1970	650576	506081	213512	152352	129908	93520	185267	28910	11797	34472
1971	410270	471051	296427	118122	83215	74030	51104	92598	20156	26245
1972	366617	305254	305838	182003	72494	50103	45122	30153	55506	27947
1973	1312010	263017	188694	185322	108922	43137	29096	27149	16912	48925
1974	1132730	1060050	160417	110708	97545	57136	25825	17876	15198	37047
1975	864773	821976	643812	88838	59831	48609	32888	15753	10162	29077
1976	692682	548525	450535	342684	46074	29718	23712	18465	8620	20423
1977	988665	449171	330275	266210	201243	28417	17430	12780	10628	16840
1978	912345	647406	253598	182219	146168	93607	16894	10147	6787	14865
1979	891239	608629	381577	144234	102938	83416	50378	9636	5993	12245
1980	1128160	526305	290915	177429	66449	47031	37199	22538	4761	8377
1981	865944	804536	297898	135126	86149	36186	25369	20569	12348	6997
1982	2031170	655698	448153	151458	67118	43539	20882	13857	10914	10242
1983	1308490	1443460	353260	202293	69838	33268	23392	11676	7335	10880
1984	1259360	934165	777188	181001	86673	34500	17757	13351	6576	9367
1985	1848420	843888	486900	392310	89506	41365	18156	9917	6807	8150
1986	4760610	1286790	475587	269456	176694	49864	22568	9893	5502	7895
1987	1962840	3243130	633464	228453	129409	78140	22104	11575	4680	5789
1988	1770460	1432170	1546360	290743	99541	54212	37434	9107	6344	4891
1989	1186810	1270380	703021	723770	134181	44160	25017	17916	3122	4841
1990	1036520	869783	642864	351602	353191	64212	21540	12585	9019	2062
1991	914585	798177	490389	328242	185828	162794	32481	11758	7377	5991
1992	776744	651967	394198	229534	147764	93483	72635	15207	5661	6678
1993	530684	567595	339205	185748	106060	60448	51973	37617	7130	4530
1994	442947	385219	315695	167606	87929	45514	26903	34212	23315	4880
1995	1164160	340377	214579	155030	74346	42117	21652	9768	24869	19340
1996	1290360	932940	194551	101746	64911	31921	20918	10296	4685	36050
1997	2155840	1060700	488817	88535	44228	27742	15018	8839	5009	15152
1998	774928	1827460	432991	175218	38011	18319	12140	7538	4543	9902
1999	840878	601558	1009900	143943	54210	18214	10426	6242	4436	7747
2000	991191	639225	337810	544968	40139	25850	9929	6787	3512	7050
2001	540350	795939	400484	219442	274990	20887	14274	6708	5002	6871
2002	1726210	455774	350797	134668	81575	111630	12252	8670	4997	9302
2003	537804	1266050	228653	189466	64328	37549	64349	6567	6143	10916
2004	1248170	421550	612659	111405	106730	28747	18390	36518	4412	13717
2005	791655	907301	200817	346915	61062	76051	15049	12051	28709	14799
2006	922375	624505	496183	115723	217144	35145	54069	8405	8417	36159
2007	1046420	624515	334116	282853	72005	153819	25328	43503	5468	34097
2008	821795	872142	352979	203537	202618	50212	116243	20417	36033	32071
2009	1017860	614491	539583	245324	143705	153734	39699	90345	16765	60403

Table A1.4: Population numbers-at-age for North Sea Plaice taken from 2010 ICES XSA assessment, but with adjusted plusgroup as discussed in text.

Year	1	2	3	4	5	6	7	8	9	10
1957	0.077	0.229	0.255	0.304	0.347	0.208	0.274	0.314	0.290	0.290
1958	0.105	0.250	0.302	0.358	0.374	0.321	0.268	0.291	0.323	0.323
1959	0.152	0.310	0.355	0.376	0.412	0.383	0.350	0.309	0.367	0.367
1960	0.108	0.318	0.353	0.384	0.366	0.419	0.383	0.359	0.383	0.383
1961	0.097	0.289	0.344	0.357	0.417	0.330	0.361	0.437	0.381	0.381
1962	0.096	0.319	0.373	0.398	0.434	0.426	0.362	0.350	0.395	0.395
1963	0.149	0.364	0.418	0.434	0.423	0.474	0.450	0.452	0.448	0.448
1964	0.032	0.399	0.448	0.469	0.540	0.488	0.403	0.390	0.459	0.459
1965	0.068	0.267	0.397	0.412	0.355	0.508	0.417	0.352	0.410	0.410
1966	0.071	0.356	0.388	0.430	0.477	0.343	0.506	0.409	0.435	0.435
1967	0.054	0.352	0.405	0.408	0.476	0.504	0.310	0.435	0.428	0.428
1968	0.197	0.287	0.344	0.361	0.366	0.323	0.410	0.289	0.351	0.351
1969	0.149	0.313	0.327	0.341	0.315	0.428	0.295	0.399	0.356	0.356
1970	0.223	0.435	0.492	0.505	0.462	0.504	0.594	0.261	0.467	0.467
1971	0.196	0.332	0.388	0.388	0.407	0.395	0.428	0.412	0.407	0.407
1972	0.232	0.381	0.401	0.413	0.419	0.443	0.408	0.478	0.434	0.434
1973	0.113	0.394	0.433	0.542	0.545	0.413	0.387	0.480	0.475	0.475
1974	0.221	0.399	0.491	0.515	0.596	0.452	0.394	0.465	0.486	0.486
1975	0.355	0.501	0.531	0.557	0.600	0.618	0.477	0.503	0.553	0.553
1976	0.333	0.407	0.426	0.432	0.383	0.434	0.518	0.452	0.445	0.445
1977	0.323	0.472	0.495	0.500	0.665	0.420	0.441	0.533	0.514	0.514
1978	0.305	0.429	0.464	0.471	0.461	0.520	0.461	0.427	0.470	0.470
1979	0.427	0.638	0.666	0.675	0.683	0.708	0.704	0.605	0.678	0.678
1980	0.238	0.469	0.667	0.622	0.508	0.517	0.492	0.502	0.530	0.530
1981	0.178	0.485	0.576	0.600	0.582	0.450	0.505	0.534	0.536	0.536
1982	0.242	0.518	0.695	0.674	0.602	0.521	0.481	0.536	0.565	0.565
1983	0.237	0.519	0.569	0.748	0.605	0.528	0.461	0.474	0.565	0.565
1984	0.300	0.552	0.584	0.604	0.640	0.542	0.482	0.574	0.571	0.571
1985	0.262	0.473	0.492	0.698	0.485	0.506	0.507	0.489	0.539	0.539
1986	0.284	0.609	0.633	0.633	0.716	0.714	0.568	0.648	0.739	0.739
1987	0.215	0.641	0.679	0.731	0.770	0.636	0.787	0.501	0.661	0.661
1988	0.232	0.612	0.659	0.673	0.713	0.673	0.637	0.971	0.742	0.742
1989	0.211	0.581	0.593	0.617	0.637	0.618	0.587	0.586	1.251	1.251
1990	0.161	0.473	0.572	0.538	0.675	0.582	0.505	0.434	0.515	0.515
1991	0.238	0.605	0.659	0.698	0.587	0.707	0.659	0.631	0.594	0.594
1992	0.214	0.553	0.652	0.672	0.794	0.487	0.558	0.657	0.902	0.902
1993	0.220	0.487	0.605	0.648	0.746	0.710	0.318	0.378	0.771	0.771
1994	0.163	0.485	0.611	0.713	0.636	0.643	0.913	0.219	0.277	0.277
1995	0.121	0.459	0.646	0.771	0.745	0.600	0.643	0.635	0.104	0.104
1996	0.096	0.546	0.687	0.733	0.750	0.654	0.761	0.621	0.889	0.889
1997	0.065	0.796	0.926	0.746	0.781	0.726	0.589	0.566	0.611	0.611
1998	0.153	0.493	1.001	1.073	0.636	0.464	0.565	0.430	0.523	0.523
1999	0.174	0.477	0.517	1.177	0.641	0.507	0.329	0.475	0.447	0.447
2000	0.119	0.368	0.331	0.584	0.553	0.494	0.292	0.205	0.330	0.330
2001	0.070	0.719	0.990	0.890	0.802	0.433	0.399	0.195	0.144	0.144
2002	0.210	0.590	0.516	0.639	0.676	0.451	0.524	0.245	0.170	0.170
2003	0.144	0.626	0.619	0.474	0.705	0.614	0.467	0.298	0.118	0.118
2004	0.219	0.642	0.469	0.501	0.239	0.547	0.323	0.141	0.103	0.103
2005	0.137	0.504	0.451	0.369	0.452	0.241	0.482	0.259	0.085	0.085
2006	0.290	0.525	0.462	0.374	0.245	0.228	0.117	0.330	0.168	0.168
2007	0.082	0.471	0.396	0.234	0.260	0.180	0.116	0.088	0.110	0.110
2008	0.191	0.380	0.264	0.248	0.176	0.135	0.152	0.097	0.020	0.020
2009	0.168	0.426	0.257	0.204	0.184	0.129	0.086	0.087	0.035	0.035

Table A1.5: Fishing mortality-at-age for North Sea Plaice taken from the 2010 ICES XSA assessment with adjusted plusgroup.

Year	BTS-Isis	BTS-Tridens	SNS
1970			2272.52
1971			4115.48
1972			3419.04
1973			3490.6
1974			2731.37
1975			3671.22
1976			1302.31
1977			2276.69
1978			2921.2
1979			3498.43
1980			5141.19
1981			3844.22
1982			4781.09
1983			3369.44
1984			4034.47
1985	45.26		3741.39
1986	62.71		5260.06
1987	98.30		4911.93
1988	74.58		4979.08
1989	72.71		3975.19
1990	47.12		2442.32
1991	48.61		4499.28
1992	47.21		4138.53
1993	60.21		2466.78
1994	33.59		1901.9
1995	26.54		1732.16
1996	46.13	5.09	2485.38
1997	48.85	6.67	3986.73
1998	58.91	9.23	4766.81
1999	51.74	11.05	4452.05
2000	31.36	10.80	1576.88
2001	30.28	8.65	1130.47
2002	36.30	10.54	1665.43
2003	30.31	15.94	
2004	33.38	16.20	1229.38
2005	21.25	16.83	759.74
2006	18.63	20.29	909.908
2007	33.02	21.85	897.587
2008	36.64	37.93	1104.63
2009	51.01	37.52	1098.33

Table A1.6: Age-aggregated survey biomass indices for North Sea Plaice.

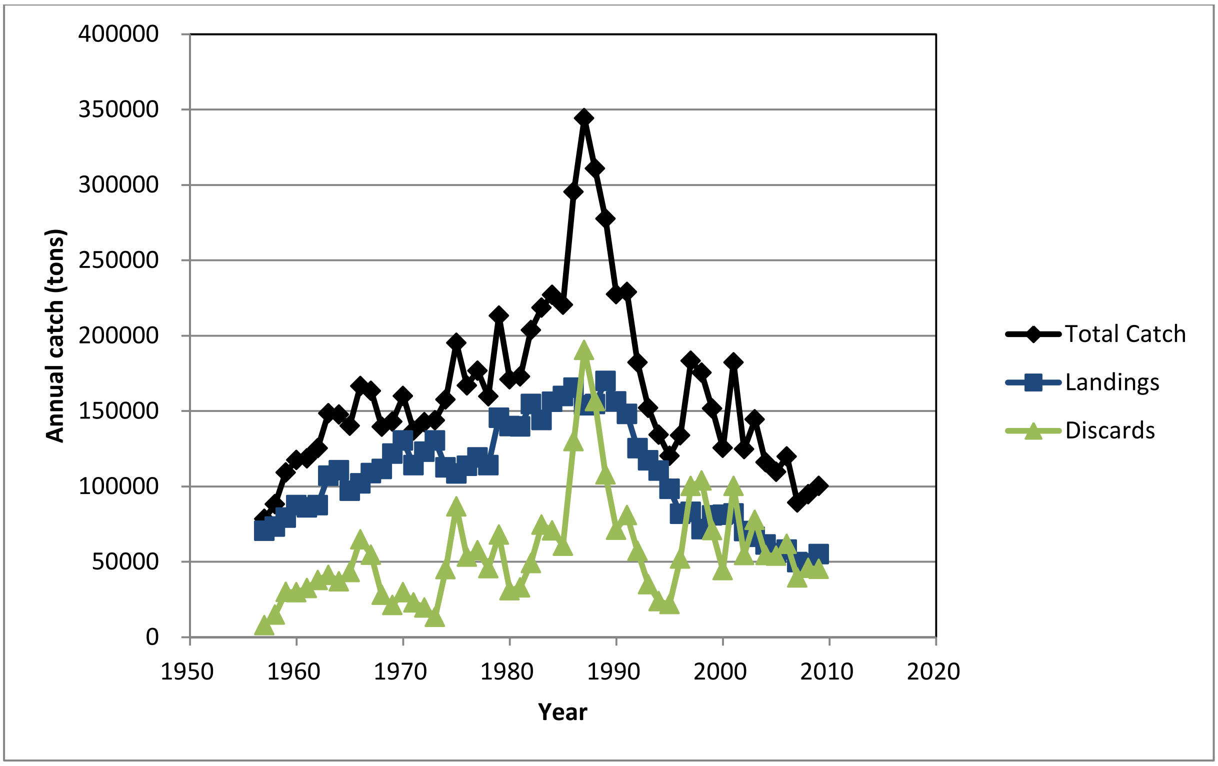


Figure A1.1: Total annual catch of North Sea Plaice in tons consisting of landings plus discards.

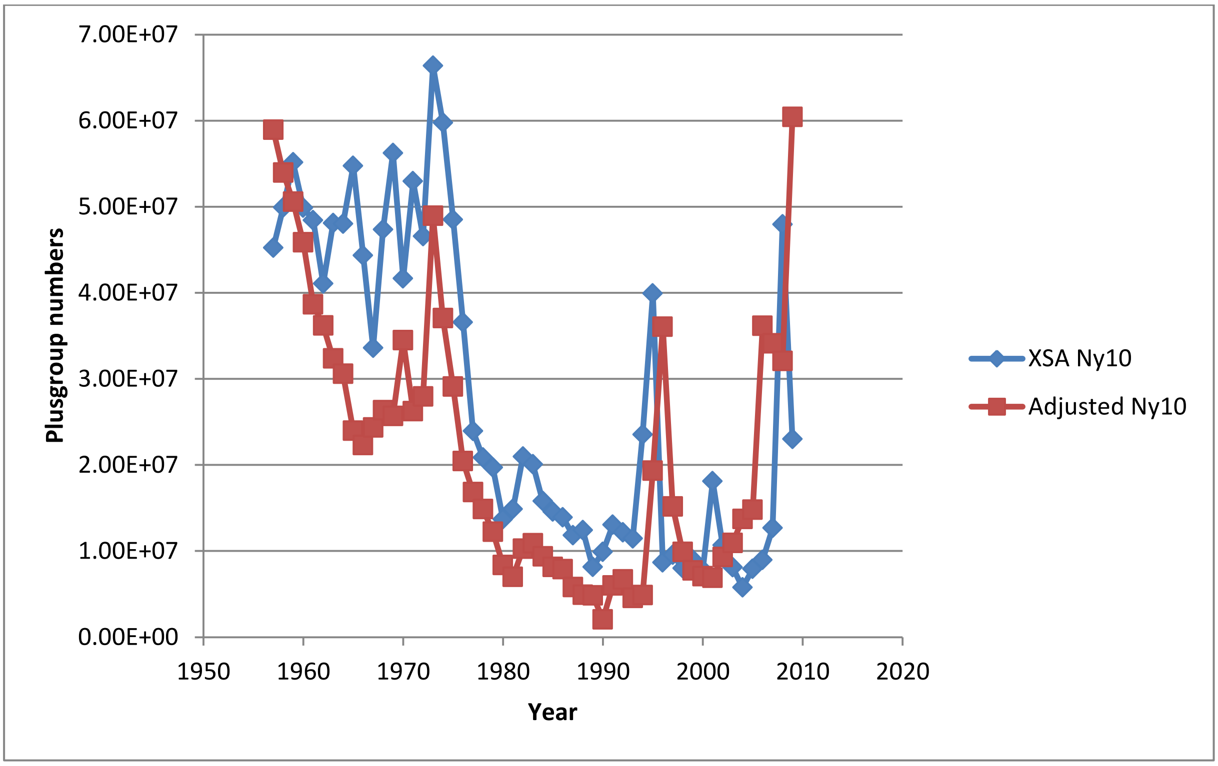


Figure A1.2: Adjusted plusgroup population numbers compared to the XSA estimates for North Sea Plaice.

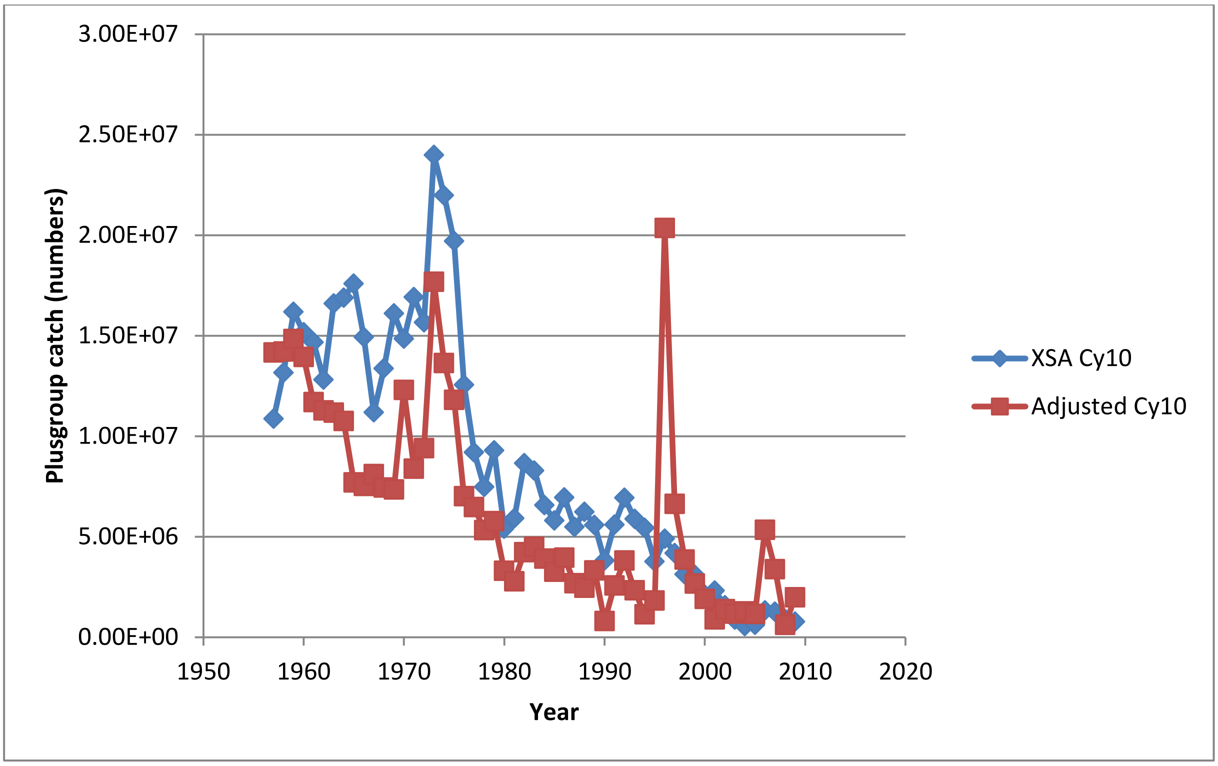


Figure A1.3: Adjusted plusgroup catch compared to observed catch for North Sea Plaice.

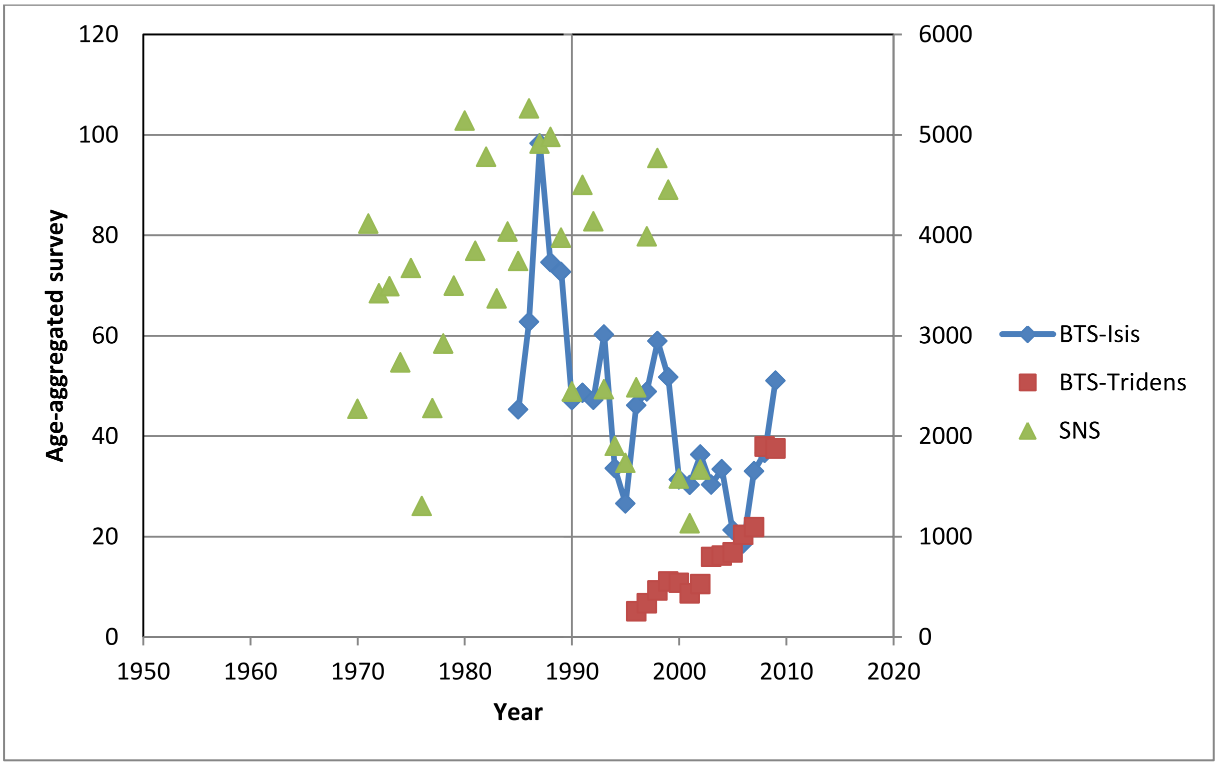


Figure A1.4: Age-aggregated survey series for North Sea Plaice.

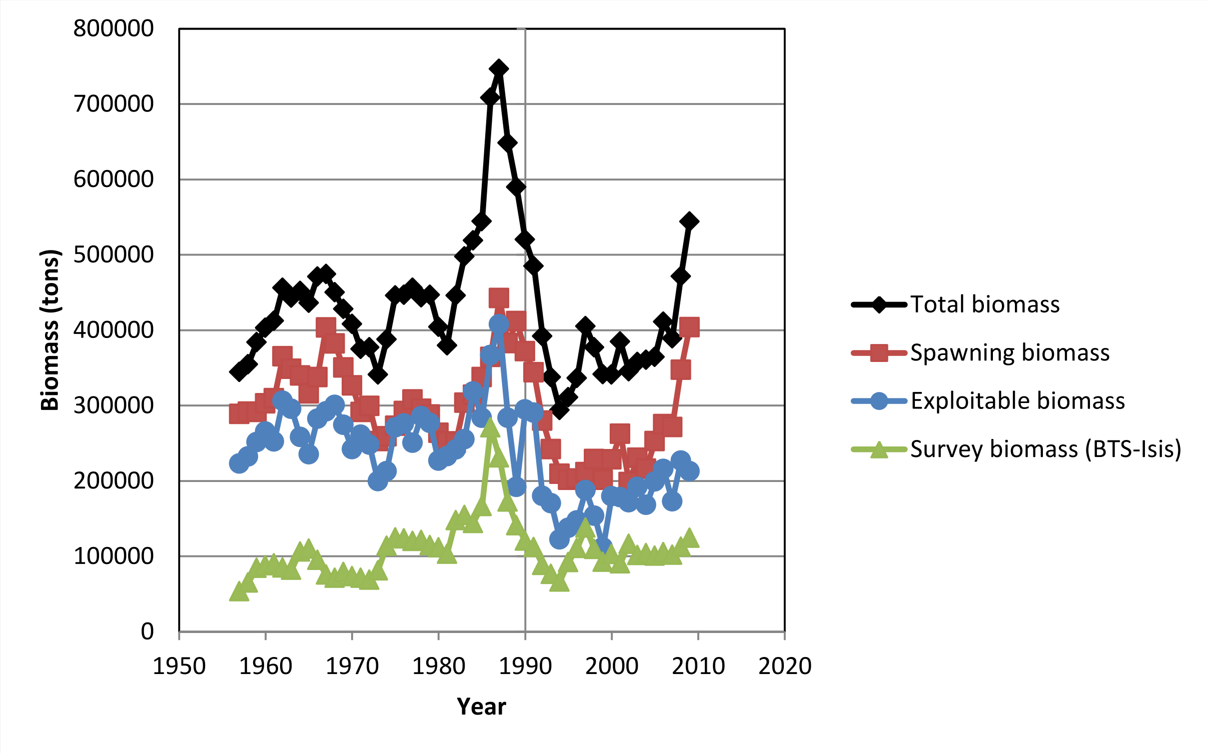


Figure A1.5: Trajectories for various biomass components from the 2010 XSA assessment with the plusgroup adjusted as detailed in text for North Sea Plaice.

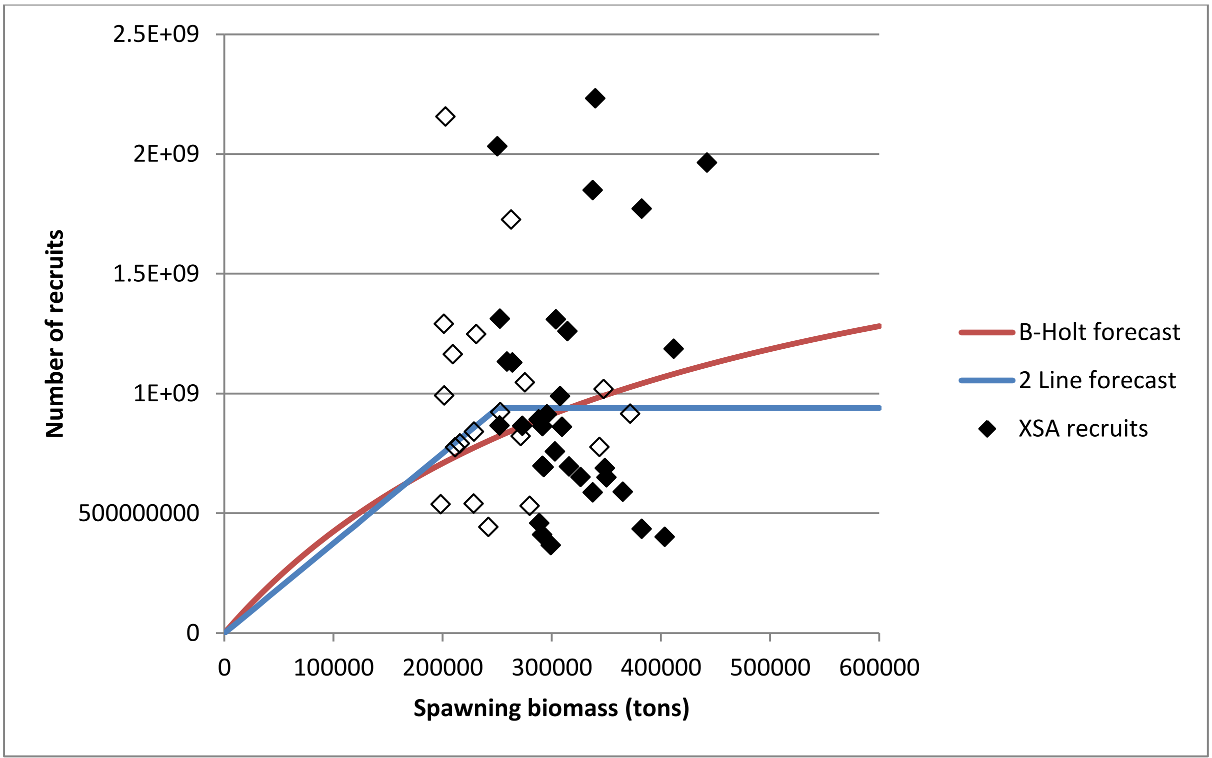


Figure A1.6: Number of recruits (1-yr-olds) estimated in the 2010 XSA assessment for North Sea Plaice (diamonds) compared to the number of recruits in terms of a Beverton Holt stock-recruitment curve when fixing *h* to 0.9 and a 2-line stock recruit relationship fitted to data from 1957 to 1989 (forecast). Recruitments from 1990 onwards are shown by open diamonds.

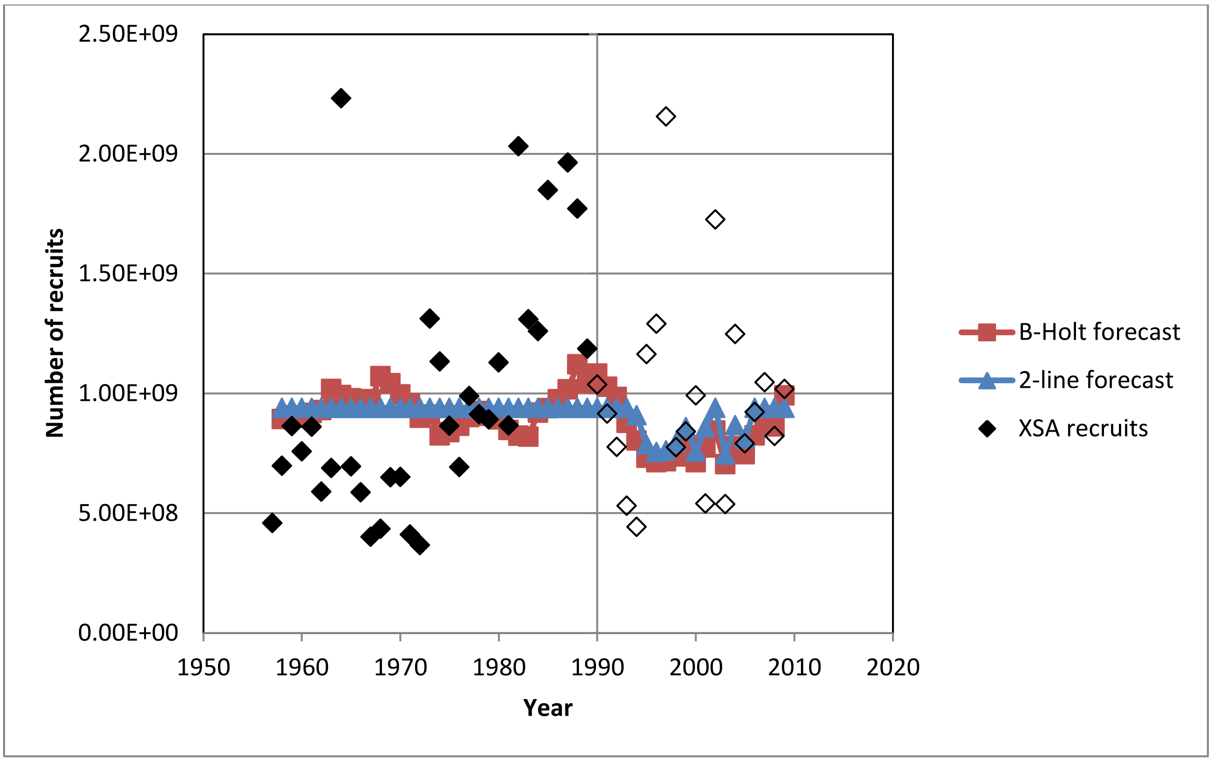


Figure A1.7: Annual number of recruits (1-yr-olds) estimated in the 2010 XSA assessment for North Sea Plaice (diamonds) compared to the annual number of recruits in terms of a Beverton Holt stock-recruitment curve fixing *h*=0.9 (squares) and a 2-line stock-recruit relationship (triangles).

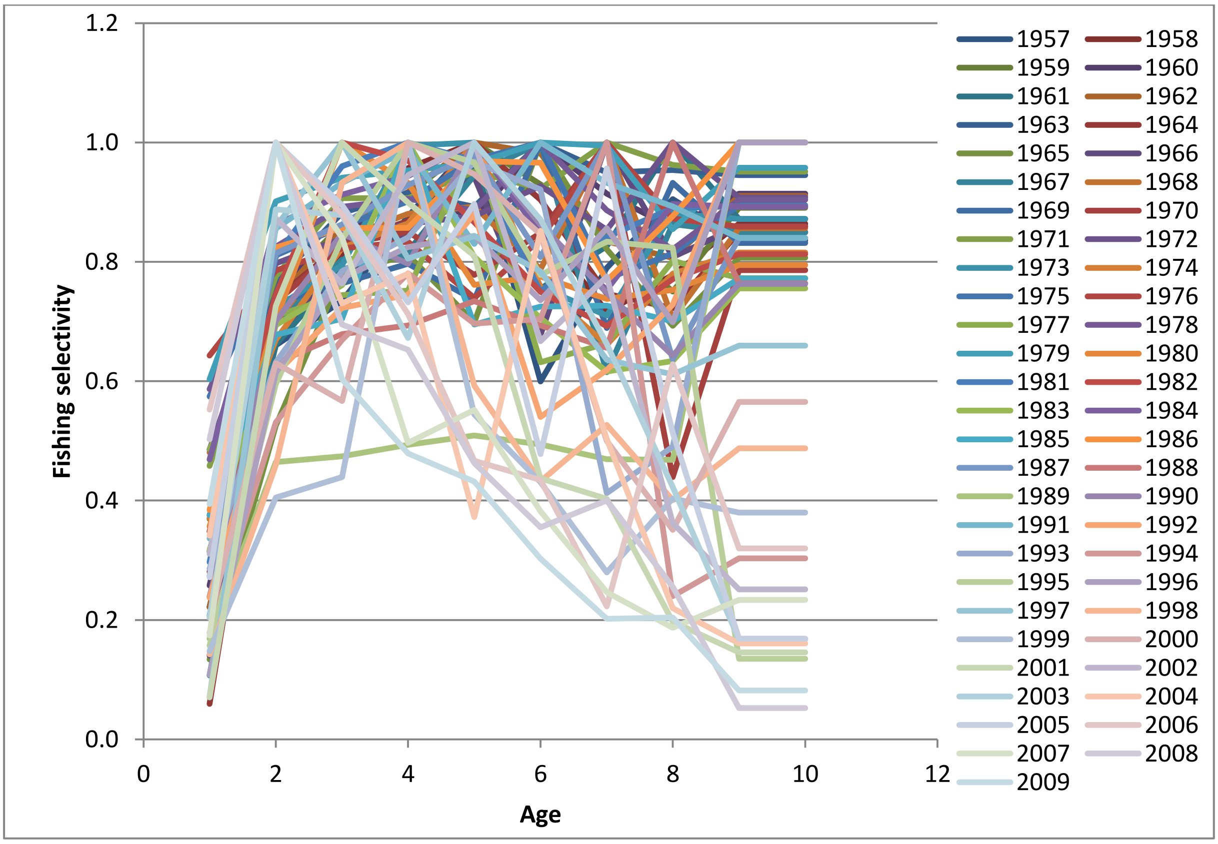


Figure A1.8: Fishing selectivities-at-age over the assessment period from 1957 to 2009 for North Sea Plaice.

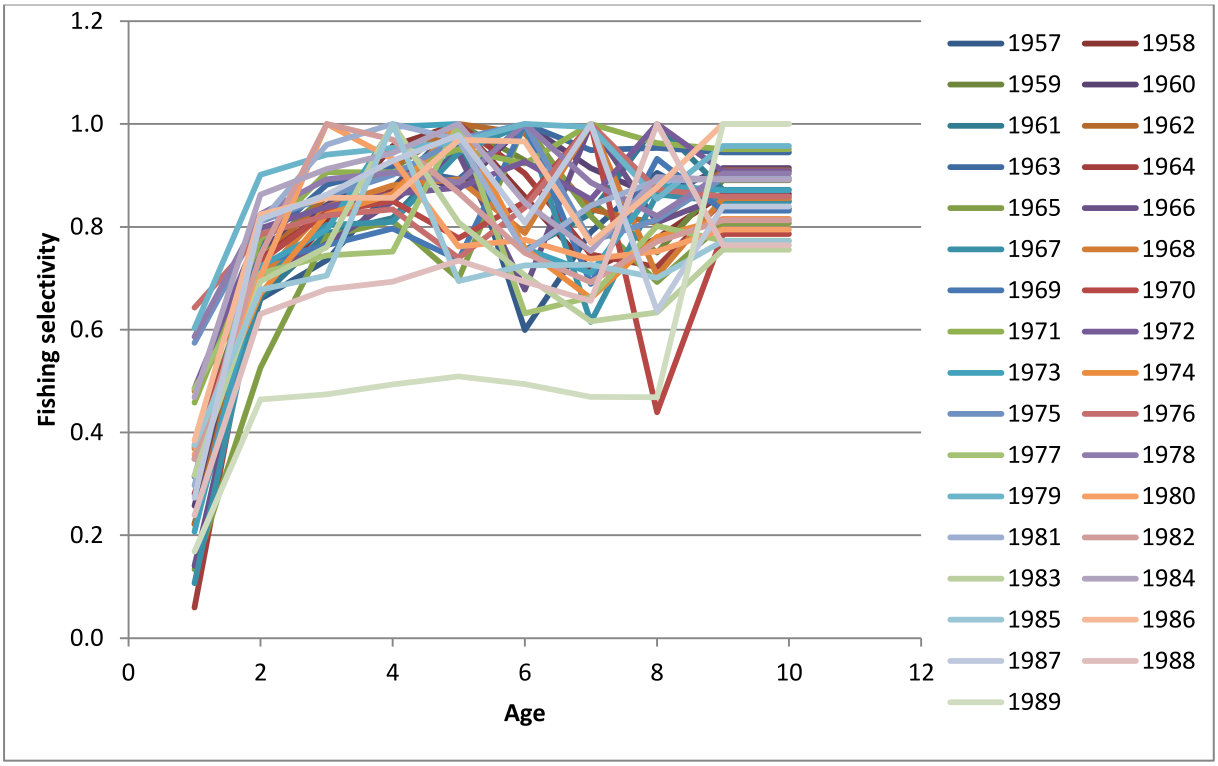
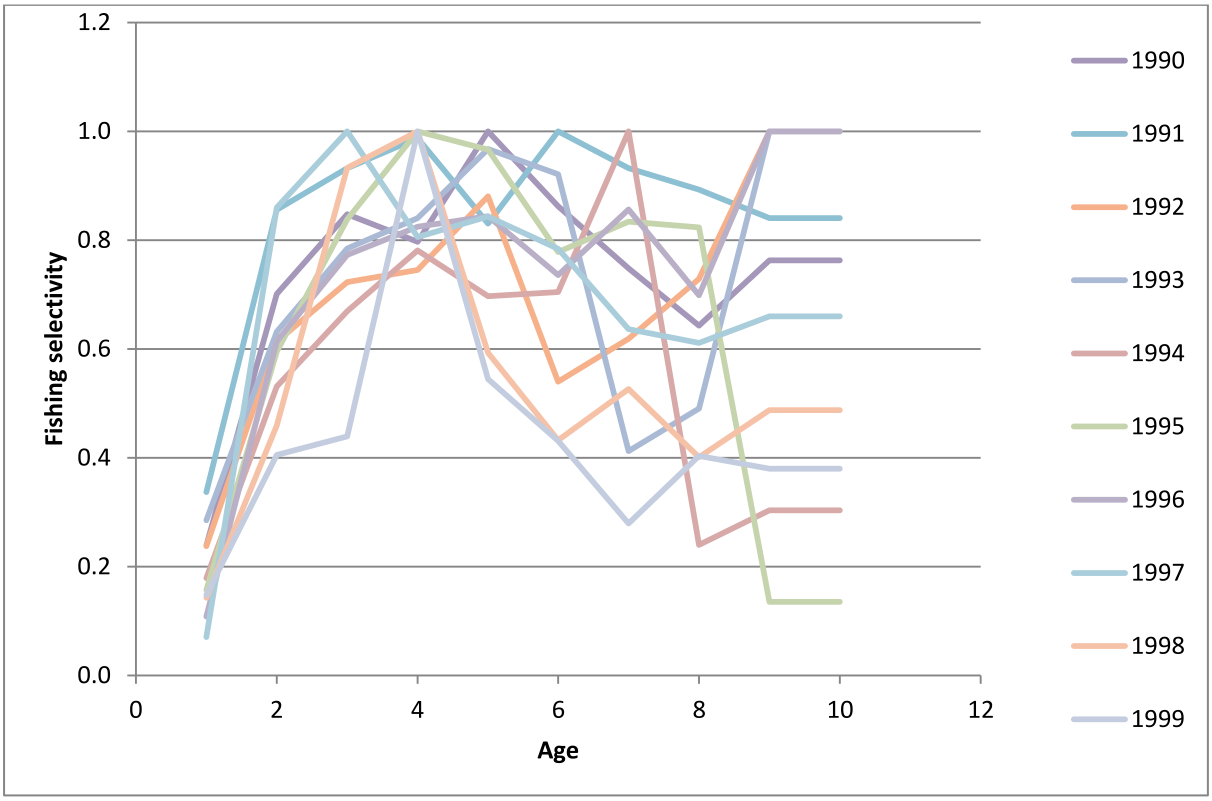


Figure A1.9: Fishing selectivities prior to the projection period from 1957 to 1989 for North Sea Plaice.



FigureA1.10: Fishing selectivities during the first decade of the projection period for North Sea Plaice.

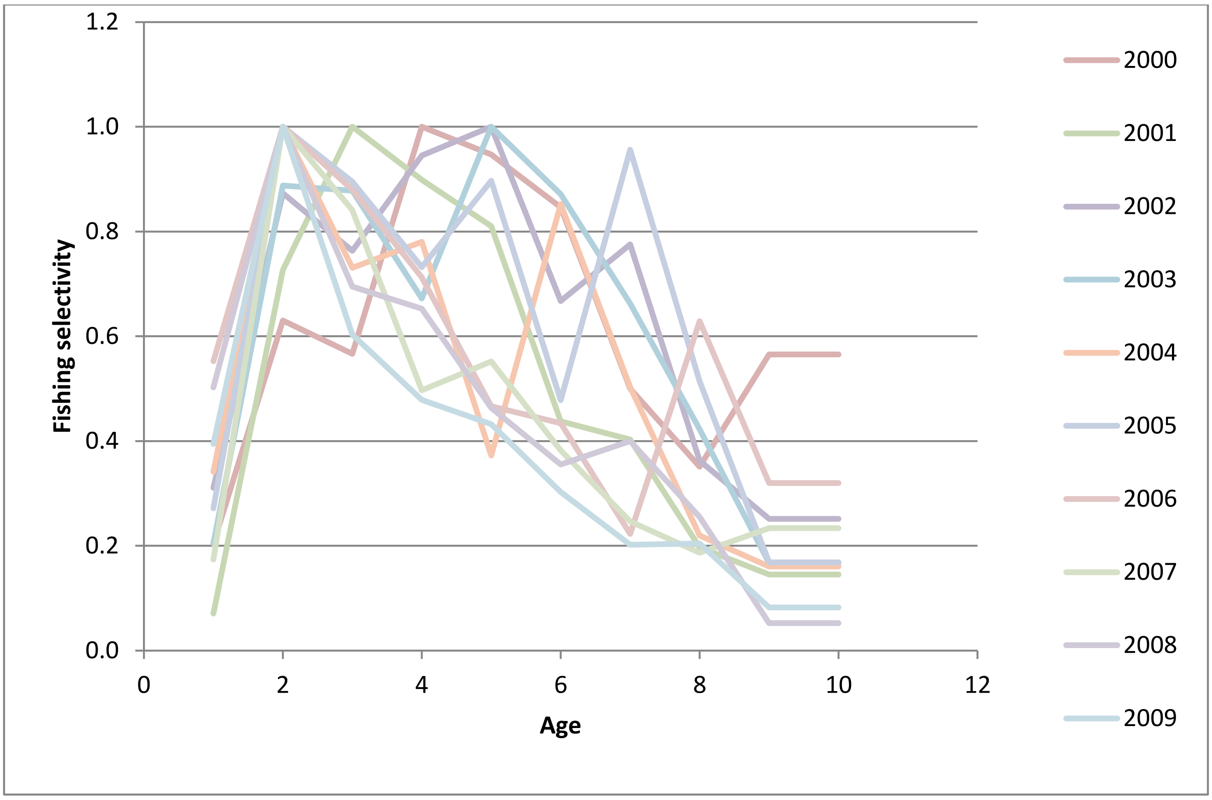


Figure A1.11: Fishing selectivities for the last decade in the projection period showing a marked decline in selectivity of older fish for North Sea Plaice.

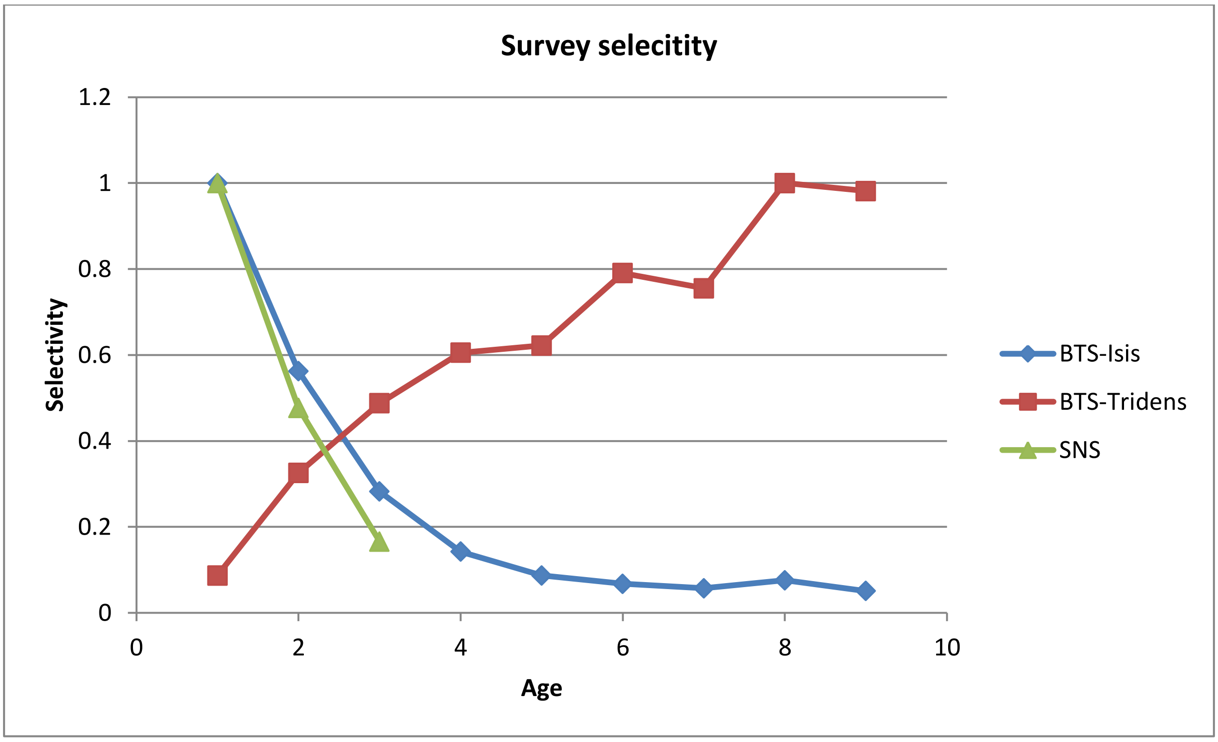


Figure A1.12: Survey selectivity vectors estimated from survey numbers-at-age as a fraction of the XSA estimated population numbers-at-age for North Sea Plaice.

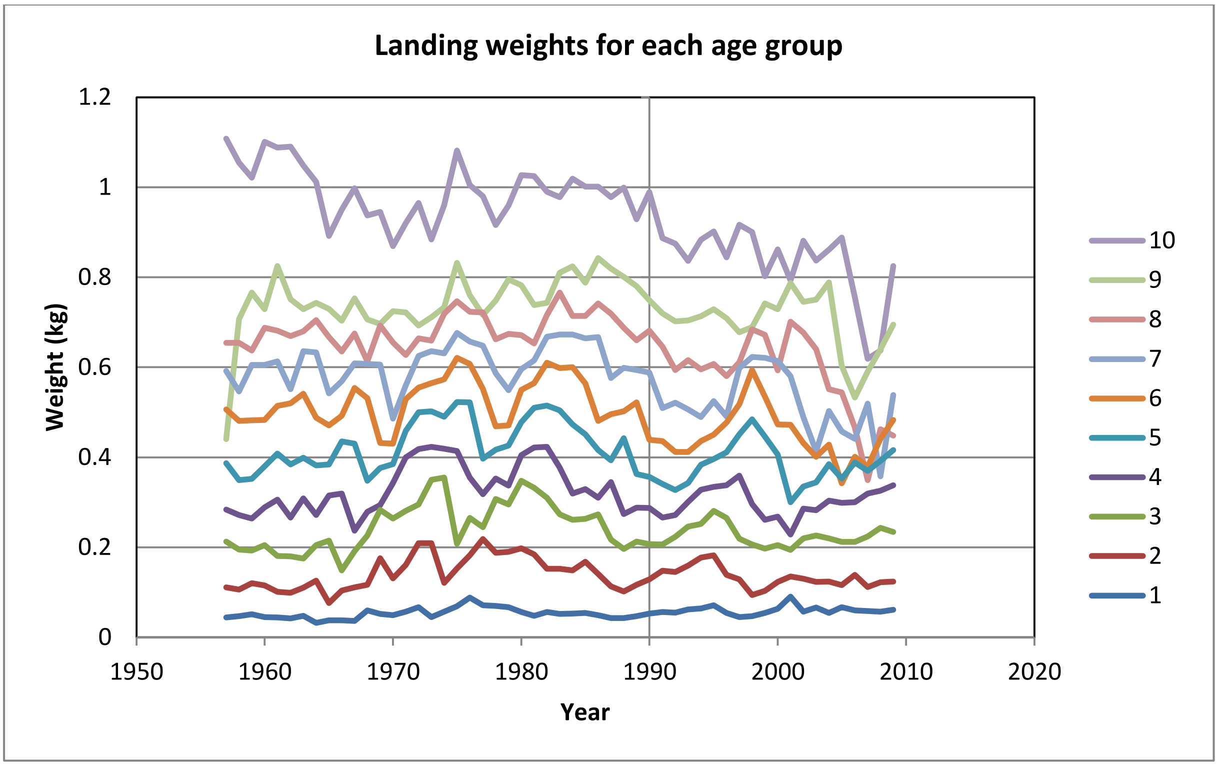


Figure A1.13 Landing weights (kg) for North Sea Plaice for each age group.

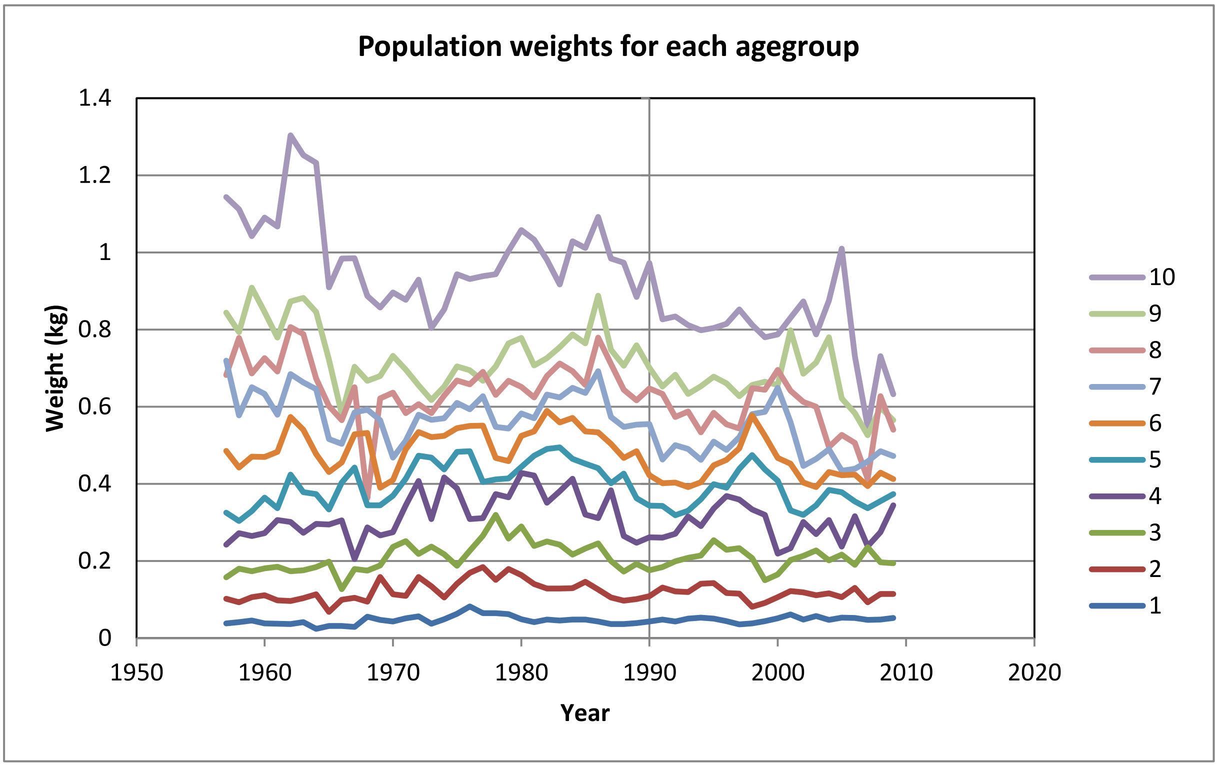


Figure A1.14 Population weights (kg) for North Sea Plaice for each age group.

Section A2: Sole in Subarea IV

The natural mortality-at-age and maturity-at-age vectors used in the XSA assessment and retrospective projections from 1990 for Sole in Subarea IV. To take into account the effect of the severe winter during 1962 to 1963, a value of 0.9 for natural mortality rate was used for 1963.

Age	1	2	3	4	5	6	7	8	9	10
Natural mortality rate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Maturity	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table A2.1: Natural mortality-at-age and maturity-at-age vectors.

The stock-recruit parameters estimated for the Beverton-Holt and 2-line functions used in the deterministic and stochastic projections.

		Beverton-Holt		2_line	
	Period	α (thousands)	β (tons)	α (thousands)	B^0 (tons)
Determinstic ("hindsight")	1957-2009	115220	8074	93345	17857
Stochastic ("forecast")	1957-1989	106895	7739	91226	22280

Table A2.2: Stock-recruit parameters.

Year	Number of recruits	Spawning biomass	Total catch
1957	128913	60713	12067
1958	128646	64446	14287
1959	488778	66599	13832
1960	61716	71980	18620
1961	99499	113421	23566
1962	22899	111614	26877
1963	20424	106822	26164
1964	539159	36250	11342
1965	121982	28686	17043
1966	39909	83085	33340
1967	75191	81938	33439
1968	99252	68048	33179
1969	50869	51582	27559
1970	137891	44507	19685
1971	42107	39149	23652
1972	76403	43523	21086
1973	105045	34480	19309
1974	109975	33280	17989
1975	40825	35680	20773
1976	113295	37232	17326
1977	140307	30380	18003
1978	47127	34920	20280
1979	11664	42679	22598
1980	151574	32895	15807
1981	148896	22280	15403
1982	152374	31867	21579
1983	141488	39308	24927
1984	70850	42631	26839
1985	81670	39661	24248
1986	159308	32562	18201
1987	72702	28693	17368
1988	455761	38698	21590
1989	108274	33199	21805
1990	177524	89328	35120
1991	70435	77064	33513
1992	353383	76294	29341
1993	69162	54425	31491
1994	56976	74044	33002
1995	95962	58771	30467
1996	49342	37138	22651
1997	270702	29097	14901
1998	113617	20843	20868
1999	82211	41474	23475
2000	123072	38011	22641
2001	62890	30306	19944
2002	183396	30855	16945
2003	83962	24764	17920
2004	44153	36962	18757
2005	48196	31460	16355
2006	216019	23789	12594
2007	55007	17857	14635
2008	81516	37490	14071
2009	102743	34414	13952

Table A2.3: Number of recruits and spawing biomass estimates from the 2010 XSA assessment, with total annual catches for Sole in Subarea IV.

Year	1	2	3	4	5	6	7	8	9	10
1957	128913	72455	89309	59106	17319	15058	27046	11837	2500	46183
1958	128646	116645	64214	71157	41456	12092	10843	18272	9062	34616
1959	488778	116404	103781	50075	50907	28474	7627	6950	12311	29191
1960	61716	442265	101846	82467	35416	37526	20278	5754	4362	29304
1961	99499	55843	388723	78710	58640	23192	25996	13739	3691	22703
1962	22899	90030	49617	304373	53013	41261	16519	19770	8361	18195
1963	20424	20719	79946	38988	219104	33371	27307	10356	13977	17730
1964	539159	8304	7993	27187	10396	59622	8154	6857	2666	7985
1965	121982	487799	7366	5222	19166	5784	37457	4405	4483	6525
1966	39909	110374	396576	5629	3204	12584	2872	22002	2504	6396
1967	75191	36111	88191	231736	4152	1776	7877	1891	13893	5680
1968	99252	68036	29169	55369	128708	1898	1097	5302	988	10948
1969	50869	88820	45250	13175	26344	70258	1278	760	3234	7082
1970	137891	45652	57613	20539	6855	12054	39659	841	455	5724
1971	42107	123534	35467	27405	10751	4505	7833	24508	527	3786
1972	76403	37700	80036	18370	12662	5462	2705	4874	15314	2407
1973	105045	68792	26889	37454	9892	6734	3453	1950	3238	10857
1974	109975	94380	50614	12171	18492	5122	3883	2179	1037	7712
1975	40825	99414	70768	25308	5793	10016	2806	2006	1346	4697
1976	113295	36689	68119	36890	11754	3256	5419	1788	952	3297
1977	140307	101523	29828	35034	20050	6051	2027	3088	1095	2039
1978	47127	125294	70623	15505	17141	11065	3783	1531	1736	2139
1979	11664	42617	89560	36039	8200	9194	5969	1770	804	2135
1980	151574	10546	30781	41875	17332	4570	5255	3739	825	1821
1981	148896	136544	8392	15951	20977	8742	2755	2665	2043	1275
1982	152374	134324	95758	4493	7902	11158	4428	1592	1568	1819
1983	141488	135343	96396	43130	2313	3788	5541	2410	855	1822
1984	70850	127653	89734	47855	18870	1499	2116	3159	1250	1272
1985	81670	63926	86270	39406	21847	8712	652	1103	1866	1277
1986	159308	73741	42036	36955	16359	10823	4501	391	637	1824
1987	72702	143792	57817	20440	16600	7433	4547	1913	249	1187
1988	455761	65694	102472	31344	10030	8826	3759	2624	872	855
1989	108274	412380	46868	47840	13872	4908	4293	1926	1527	575
1990	177524	97859	329012	25036	21738	8154	2869	2518	1127	1302
1991	70435	159810	77190	198343	13363	10924	4192	1604	1139	1062
1992	353383	63618	132081	45664	105355	5695	6388	2142	767	649
1993	69162	318822	51065	77298	25905	58879	2797	2888	1233	581
1994	56976	62529	240492	30255	40065	10247	30413	1114	1487	997
1995	95962	50871	49155	134466	14487	18427	3840	16760	567	792
1996	49342	82263	33885	28476	56443	7108	9723	1576	9444	557
1997	270702	44482	56528	15260	9629	25144	2762	4251	529	5718
1998	113617	243429	34497	28652	6840	3854	10582	1356	1634	1916
1999	82211	102573	166378	16812	11719	2864	1641	5040	472	1081
2000	123072	74114	77819	81610	7424	4791	1438	853	2673	369
2001	62890	109124	52724	39272	33128	3590	1979	537	358	1745
2002	183396	56064	74154	27165	16628	14061	1891	997	225	965
2003	83962	164940	40215	35848	12889	7231	6590	1071	335	629
2004	44153	74975	118490	19743	17131	6126	2828	3651	589	521
2005	48196	39460	53619	61584	8805	8408	3484	1702	2390	307
2006	216019	42510	28650	26504	27640	3913	3852	1703	954	1597
2007	55007	188980	29247	16307	15098	14889	2045	2027	871	1385
2008	81516	49471	133054	16108	8623	8200	8228	1067	1141	807
2009	102743	71932	38866	85491	8984	5072	5188	5008	548	981

Table A2.4: Population numbers-at-age for Sole in Subarea IV taken from 2010 ICES XSA assessment, but with plusgroup adjusted as described in text.

Year	1	2	3	4	5	6	7	8	9	10
1957	0.000	0.021	0.127	0.255	0.259	0.228	0.292	0.167	0.241	0.241
1958	0.000	0.017	0.149	0.235	0.276	0.361	0.345	0.295	0.303	0.303
1959	0.000	0.034	0.130	0.246	0.205	0.239	0.182	0.366	0.248	0.248
1960	0.000	0.029	0.158	0.241	0.323	0.267	0.289	0.344	0.294	0.294
1961	0.000	0.018	0.145	0.295	0.252	0.239	0.174	0.397	0.272	0.272
1962	0.000	0.019	0.141	0.229	0.363	0.313	0.367	0.247	0.304	0.304
1963	0.000	0.053	0.179	0.422	0.402	0.509	0.482	0.457	0.479	0.479
1964	0.000	0.020	0.326	0.250	0.486	0.365	0.516	0.325	0.390	0.390
1965	0.000	0.107	0.169	0.388	0.321	0.600	0.432	0.465	0.443	0.443
1966	0.000	0.124	0.437	0.204	0.490	0.368	0.318	0.360	0.349	0.349
1967	0.000	0.114	0.365	0.488	0.683	0.382	0.296	0.549	0.481	0.481
1968	0.011	0.308	0.695	0.643	0.505	0.296	0.268	0.394	0.422	0.422
1969	0.008	0.333	0.690	0.553	0.682	0.472	0.318	0.412	0.489	0.489
1970	0.010	0.152	0.643	0.547	0.320	0.331	0.381	0.367	0.390	0.390
1971	0.011	0.334	0.558	0.672	0.577	0.410	0.374	0.370	0.483	0.483
1972	0.005	0.238	0.659	0.519	0.531	0.358	0.227	0.309	0.390	0.390
1973	0.007	0.207	0.693	0.606	0.558	0.451	0.360	0.532	0.503	0.503
1974	0.001	0.188	0.593	0.642	0.513	0.502	0.561	0.382	0.522	0.522
1975	0.007	0.278	0.551	0.667	0.476	0.514	0.351	0.645	0.506	0.506
1976	0.010	0.107	0.565	0.510	0.564	0.374	0.463	0.391	0.634	0.634
1977	0.013	0.263	0.554	0.615	0.494	0.370	0.181	0.476	0.282	0.282
1978	0.001	0.236	0.573	0.537	0.523	0.517	0.660	0.544	0.496	0.496
1979	0.001	0.225	0.660	0.632	0.485	0.459	0.368	0.663	0.379	0.379
1980	0.004	0.128	0.557	0.591	0.584	0.406	0.579	0.504	0.630	0.630
1981	0.003	0.255	0.525	0.602	0.531	0.580	0.449	0.430	0.501	0.501
1982	0.019	0.232	0.698	0.564	0.635	0.600	0.508	0.521	0.520	0.520
1983	0.003	0.311	0.600	0.727	0.334	0.482	0.462	0.556	0.644	0.644
1984	0.003	0.292	0.723	0.684	0.673	0.733	0.552	0.426	0.581	0.581
1985	0.002	0.319	0.748	0.779	0.602	0.561	0.411	0.448	0.444	0.444
1986	0.002	0.143	0.621	0.700	0.689	0.767	0.756	0.351	0.629	0.629
1987	0.001	0.239	0.512	0.612	0.532	0.582	0.450	0.686	0.419	0.419
1988	0.000	0.238	0.662	0.715	0.615	0.621	0.569	0.442	0.999	0.999
1989	0.001	0.126	0.527	0.689	0.431	0.437	0.434	0.436	0.379	0.379
1990	0.005	0.137	0.406	0.528	0.588	0.565	0.482	0.694	0.727	0.727
1991	0.002	0.091	0.425	0.533	0.753	0.436	0.572	0.637	1.121	1.121
1992	0.003	0.120	0.436	0.467	0.482	0.611	0.694	0.452	0.791	0.791
1993	0.001	0.182	0.423	0.557	0.827	0.561	0.820	0.564	0.499	0.499
1994	0.013	0.141	0.481	0.636	0.677	0.882	0.496	0.576	1.043	1.043
1995	0.054	0.306	0.446	0.768	0.612	0.539	0.790	0.474	0.792	0.792
1996	0.004	0.275	0.698	0.984	0.709	0.845	0.727	0.991	0.459	0.459
1997	0.006	0.154	0.580	0.702	0.816	0.765	0.611	0.856	1.082	1.082
1998	0.002	0.281	0.619	0.794	0.771	0.754	0.642	0.955	1.089	1.089
1999	0.004	0.176	0.612	0.717	0.794	0.589	0.554	0.534	1.336	1.336
2000	0.020	0.241	0.584	0.802	0.627	0.784	0.886	0.768	0.456	0.456
2001	0.015	0.286	0.563	0.759	0.757	0.541	0.585	0.769	0.679	0.679
2002	0.006	0.232	0.627	0.646	0.733	0.658	0.469	0.992	0.537	0.537
2003	0.013	0.231	0.611	0.638	0.644	0.839	0.490	0.499	0.515	0.515
2004	0.012	0.235	0.554	0.707	0.612	0.464	0.408	0.324	1.187	1.187
2005	0.026	0.220	0.605	0.701	0.711	0.681	0.616	0.479	0.424	0.424
2006	0.034	0.274	0.464	0.463	0.519	0.549	0.542	0.570	0.511	0.511
2007	0.006	0.251	0.496	0.537	0.510	0.493	0.551	0.475	0.928	0.928
2008	0.025	0.141	0.342	0.484	0.431	0.358	0.397	0.567	0.586	0.586
2009	0.017	0.164	0.341	0.391	0.479	0.415	0.385	0.384	0.899	0.899

Table A2.5: Fishing mortality-at-age for Sole in Subarea IV taken from the 2010 ICES XSA assessment, but with plusgroup adjusted as described in text.

Year	BTS-isis	SNS
1957		
1958		
1959		
1960		
1961		
1962		
1963		
1964		
1965		
1966		
1967		
1968		
1969		
1970		293.271
1971		326.698
1972		129.932
1973		388.106
1974		149.056
1975		188.455
1976		113.629
1977		278.598
1978		312.679
1979		151.525
1980		222.524
1981		396.531
1982		487.724
1983		323.870
1984		355.336
1985	2.709	315.860
1986	2.003	267.961
1987	3.190	260.693
1988	6.819	716.098
1989	11.912	863.145
1990	11.015	523.502
1991	7.270	667.303
1992	11.310	698.119
1993	10.028	579.423
1994	5.658	268.420
1995	6.043	226.161
1996	3.088	75.031
1997	10.290	579.225
1998	5.459	690.122
1999	6.940	297.214
2000	2.854	156.842
2001	2.810	170.643
2002	2.772	470.770
2003	3.117	
2004	1.898	247.183
2005	1.664	76.286
2006	1.637	166.041
2007	3.942	195.469
2008	5.085	167.186
2009	3.350	180.814

Table A2.6: Age-aggregated survey biomass indices for Sole in Subarea IV.

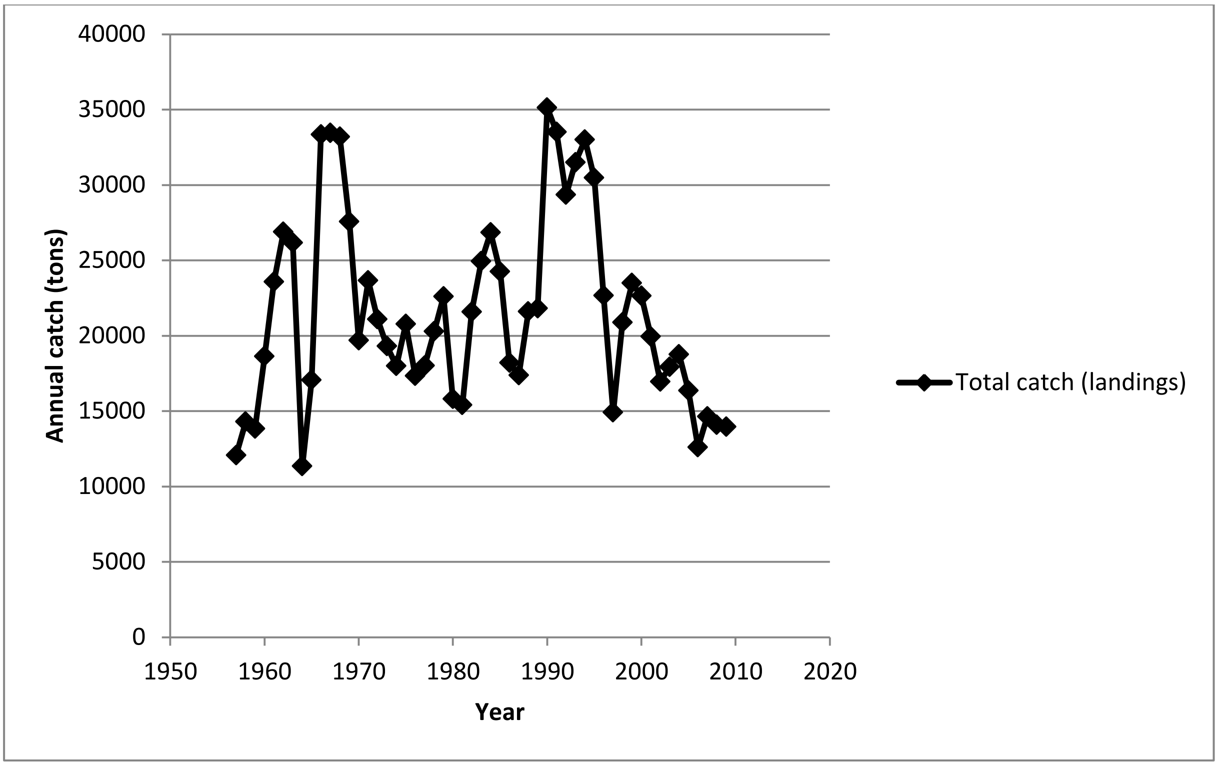


Figure A2.1: Total annual landings of Sole in Subarea IV in tons.

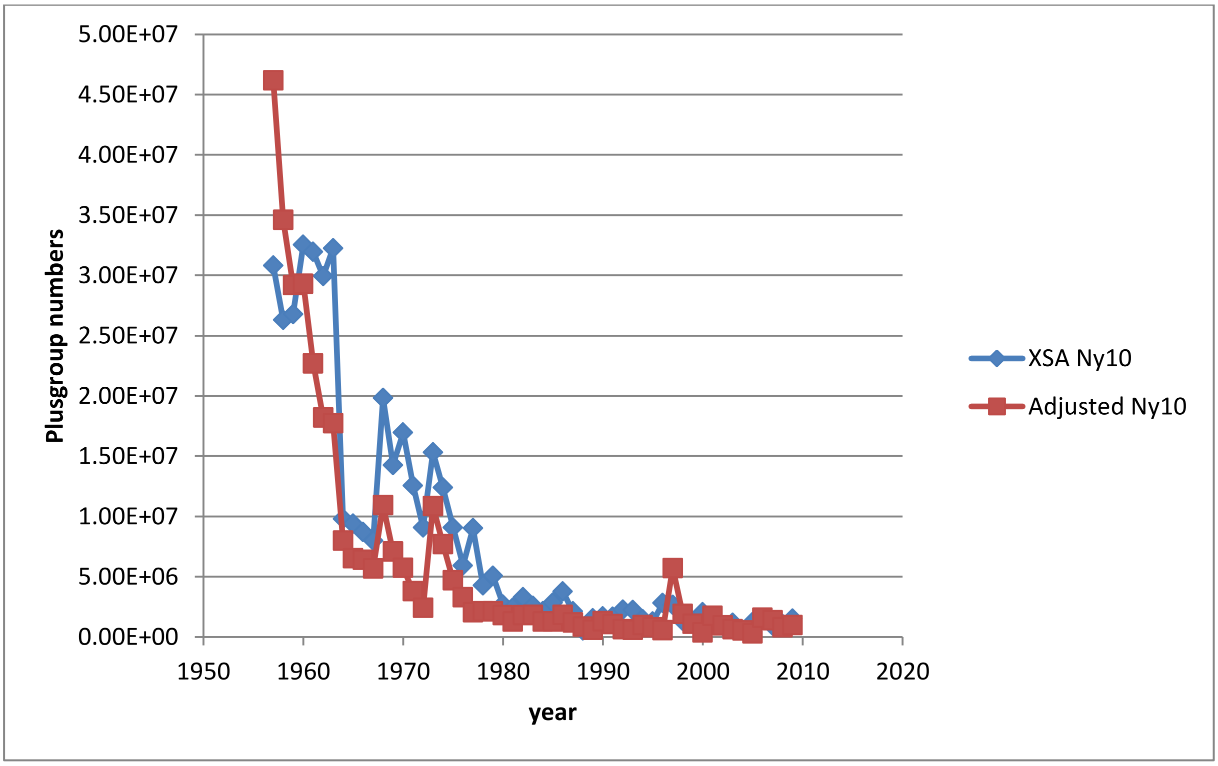


Figure A2.2: Adjusted plusgroup population numbers compared to the XSA estimates for Sole in Subarea IV.

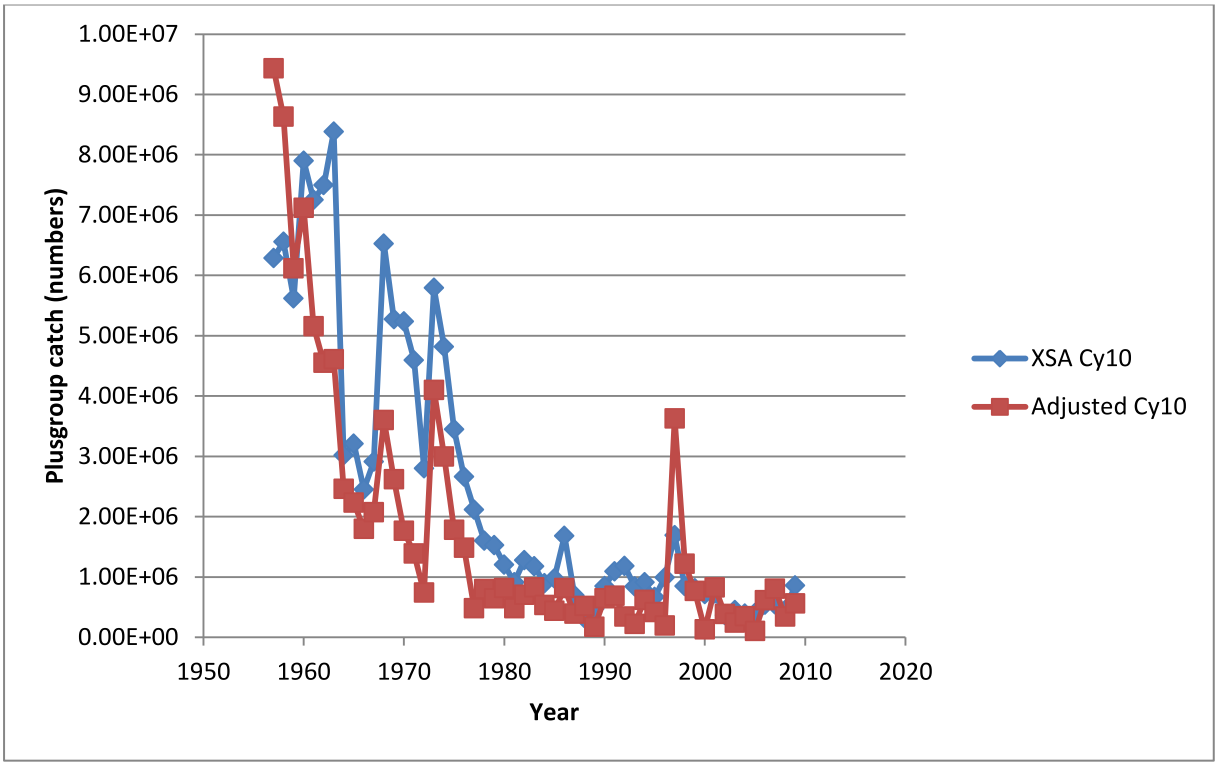


Figure A2.3: Adjusted plusgroup catch compared to observed catch for Sole in Subarea IV.

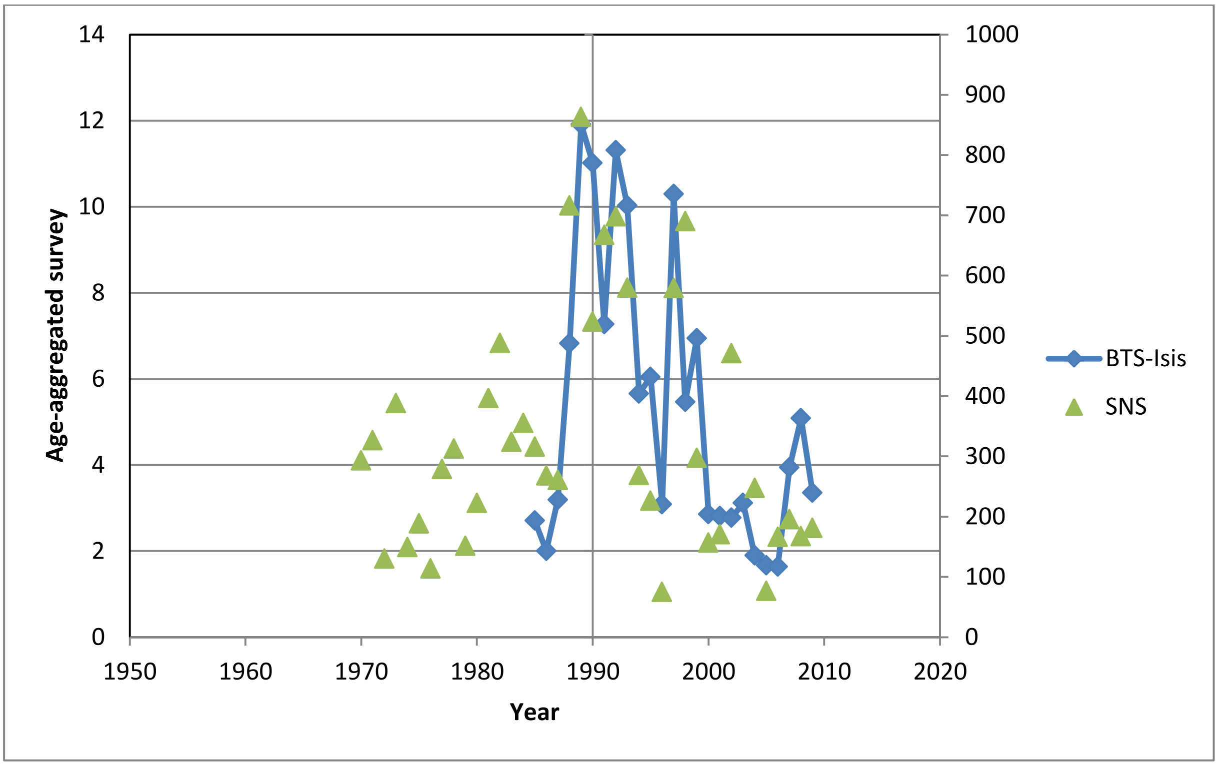


Figure A2.4: Age-aggregated survey series for Sole in Subarea IV.

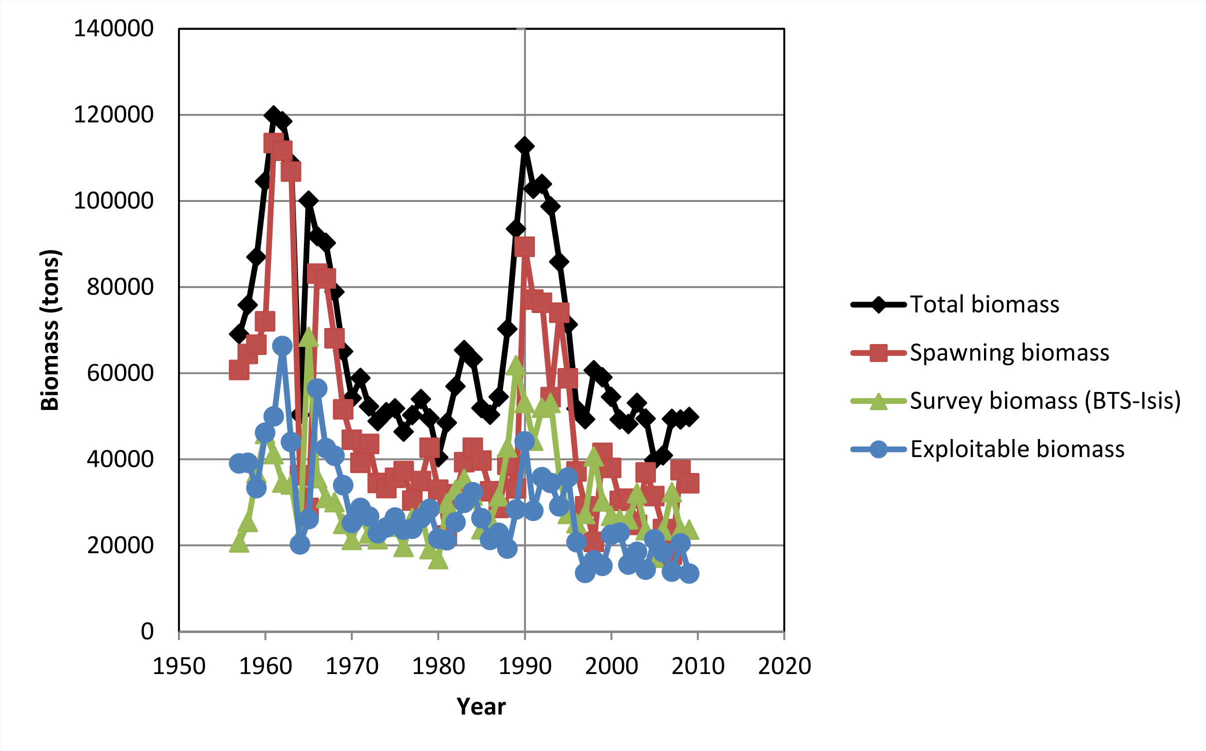


Figure A2.5: Trajectories for various biomass components from the XSA assessment for Sole in Subarea IV with plusgroup adjusted as detailed in the text.

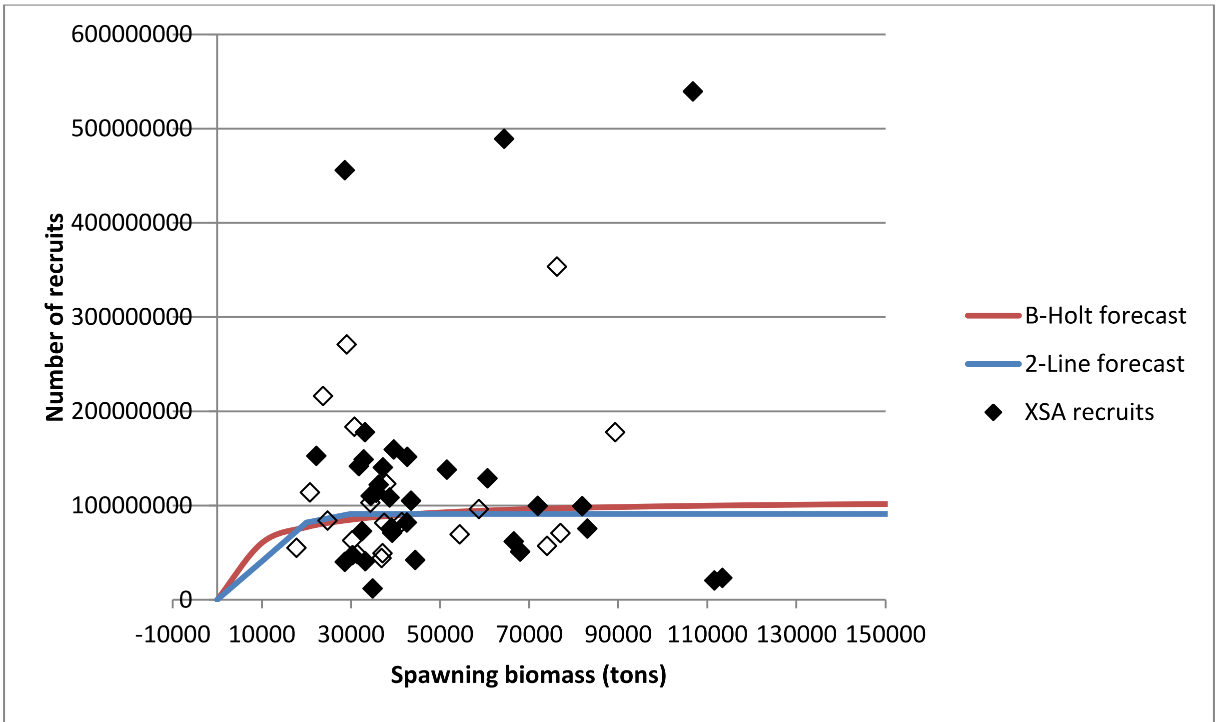


Figure A2.6: Number of recruits (1-yr-olds) estimated in the 2010 XSA assessment for Sole in Subarea IV (diamonds) and number of recruits in terms of a Beverton Holt stock-recruitment curve when fixing *h*=0.9 and a 2-line stock-recruit relationship fitted to data from 1957 to 1989 (forecast) . Recruitments from 1990 onwards are shown by open diamonds.

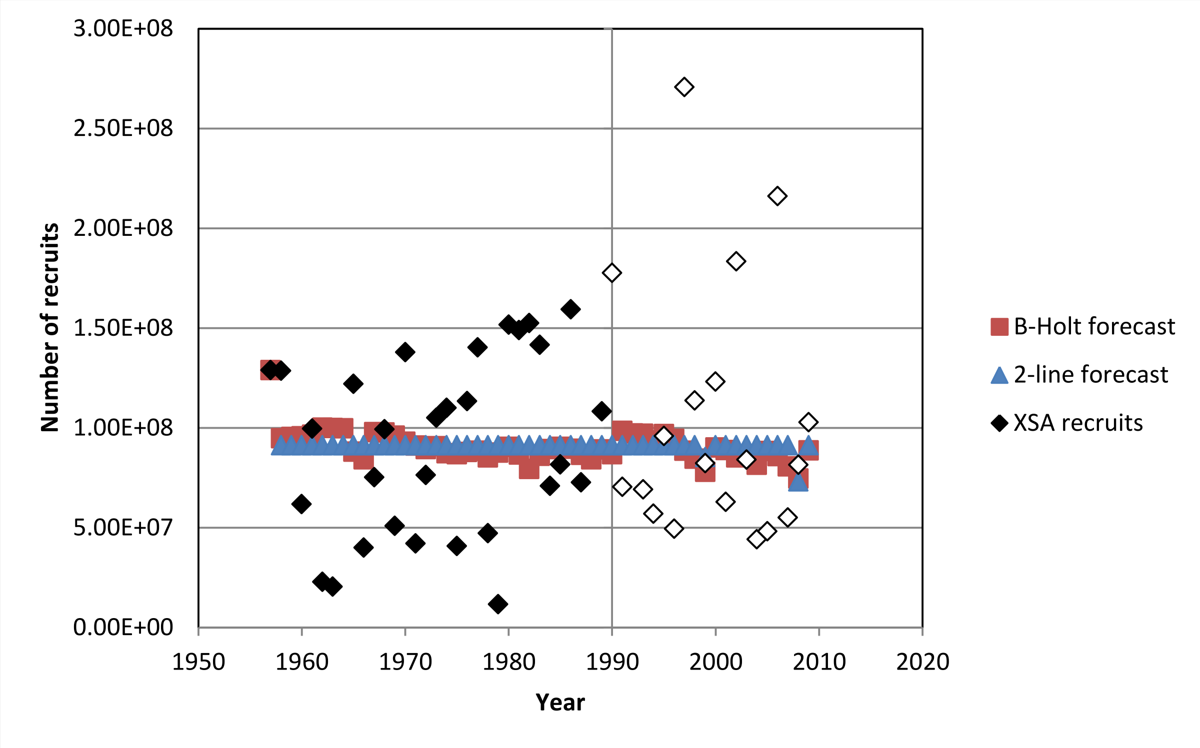


Figure A2.7: Annual number of recruits (1-yr-olds) estimated in the 2010 XSA assessment for Sole in Subarea IV (diamonds) compared to the number of recruits in terms of a Beverton Holt stock-recruitment curve when fixing *h=0.9* (squares) and a 2-line stock-recruit relationship.

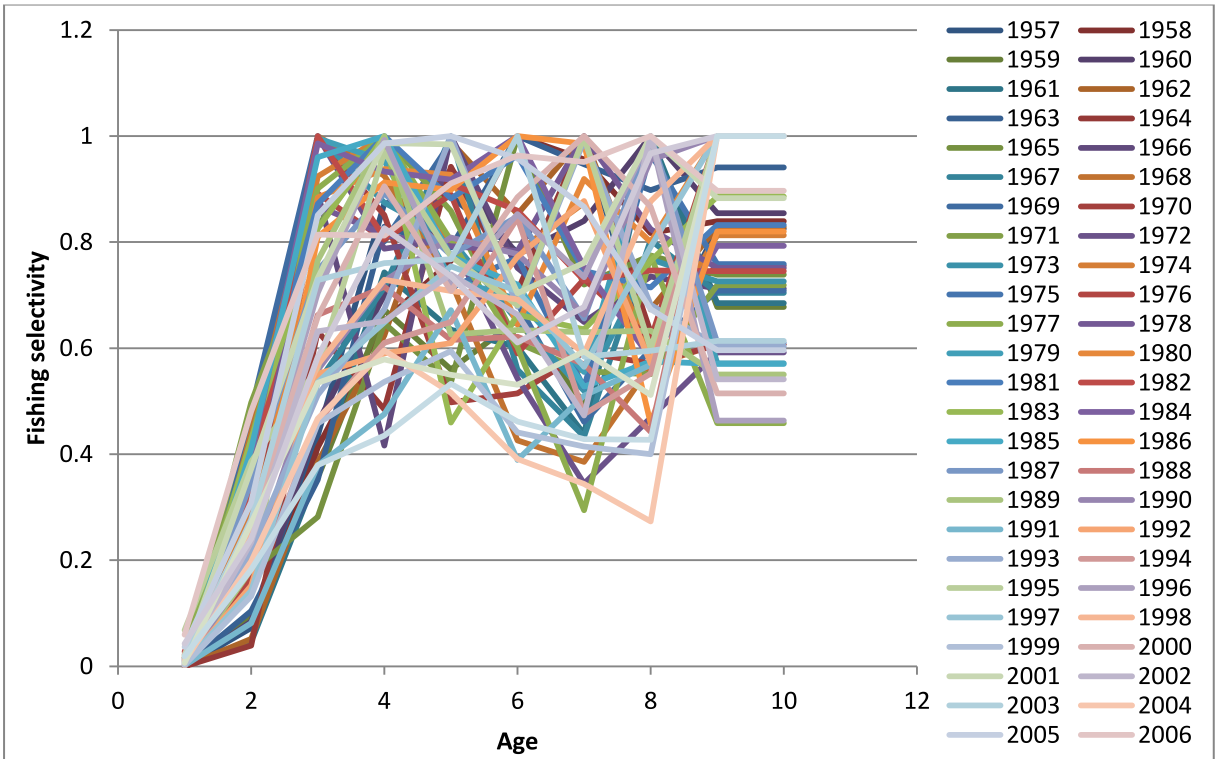


Figure A2.8: Fishing selectivities-at-age over the assessment period from 1957 to 2009 for Sole (Subarea IV).

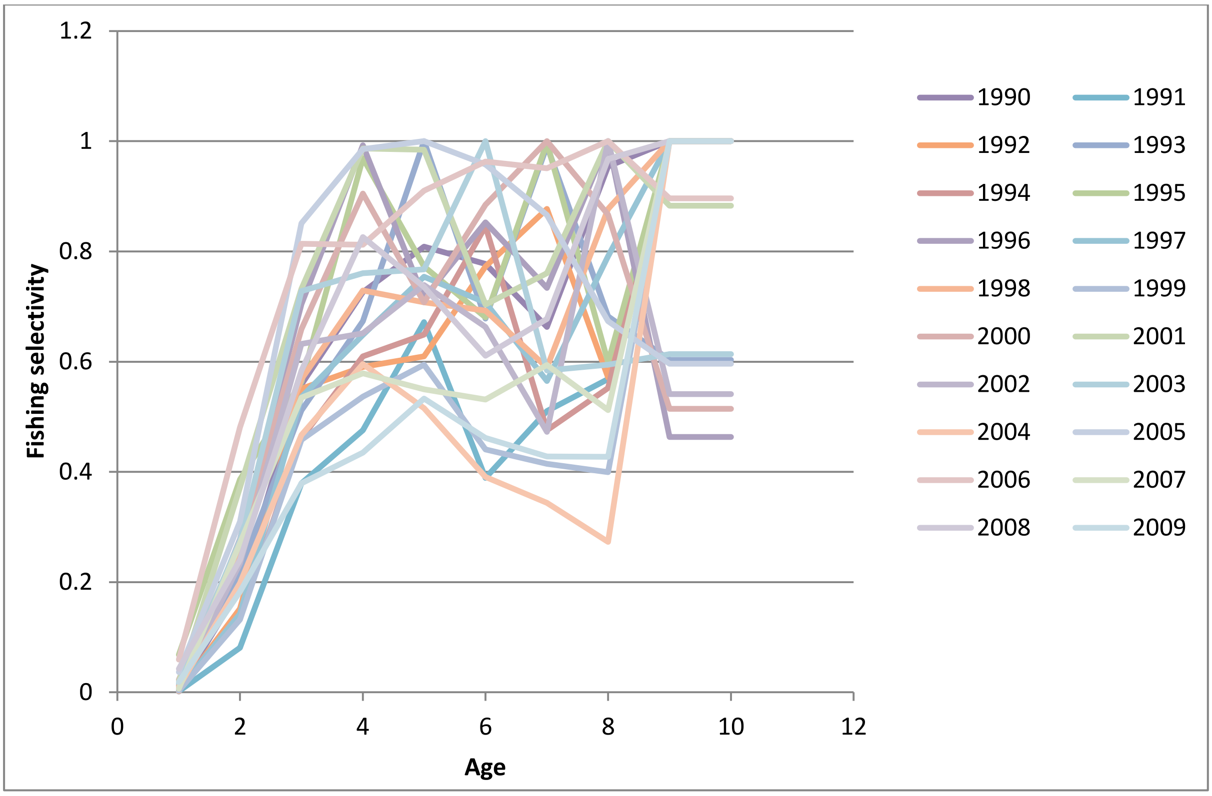


Figure A2.9: Fishing selectivities for Sole in Subarea IV during the projection period.

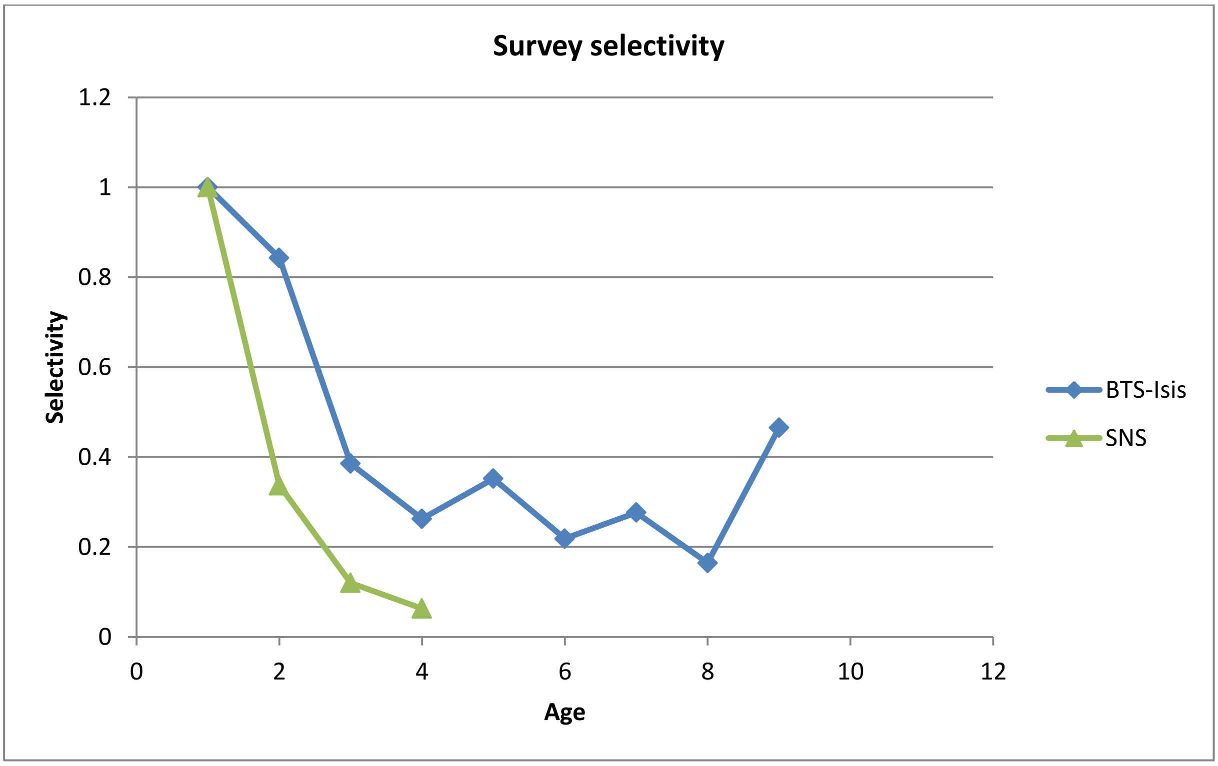


Figure A2.10: Survey selectivity vectors estimated from survey numbers-at-age as a fraction of the adjusted XSA estimated population numbers-at-age for Sole in Subarea IV.

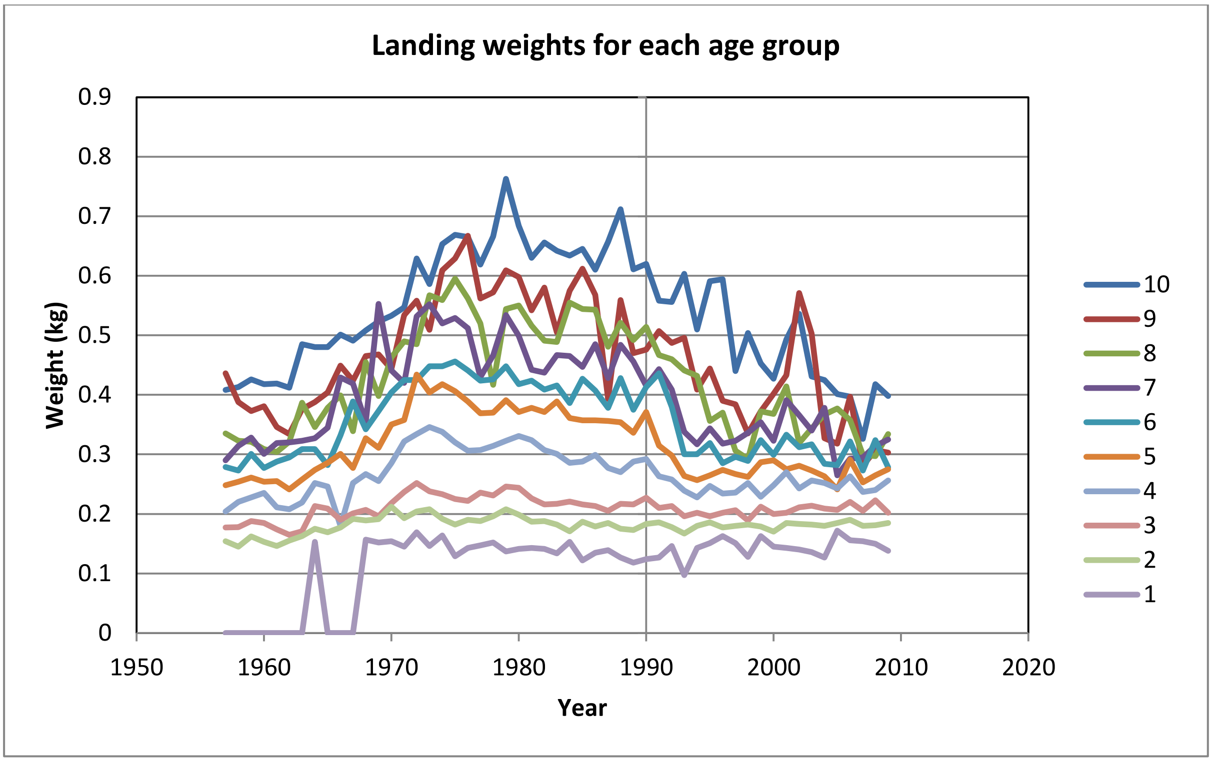


Figure A2.11 Landing weights (kg) for Sole in Subarea IV for each age group.

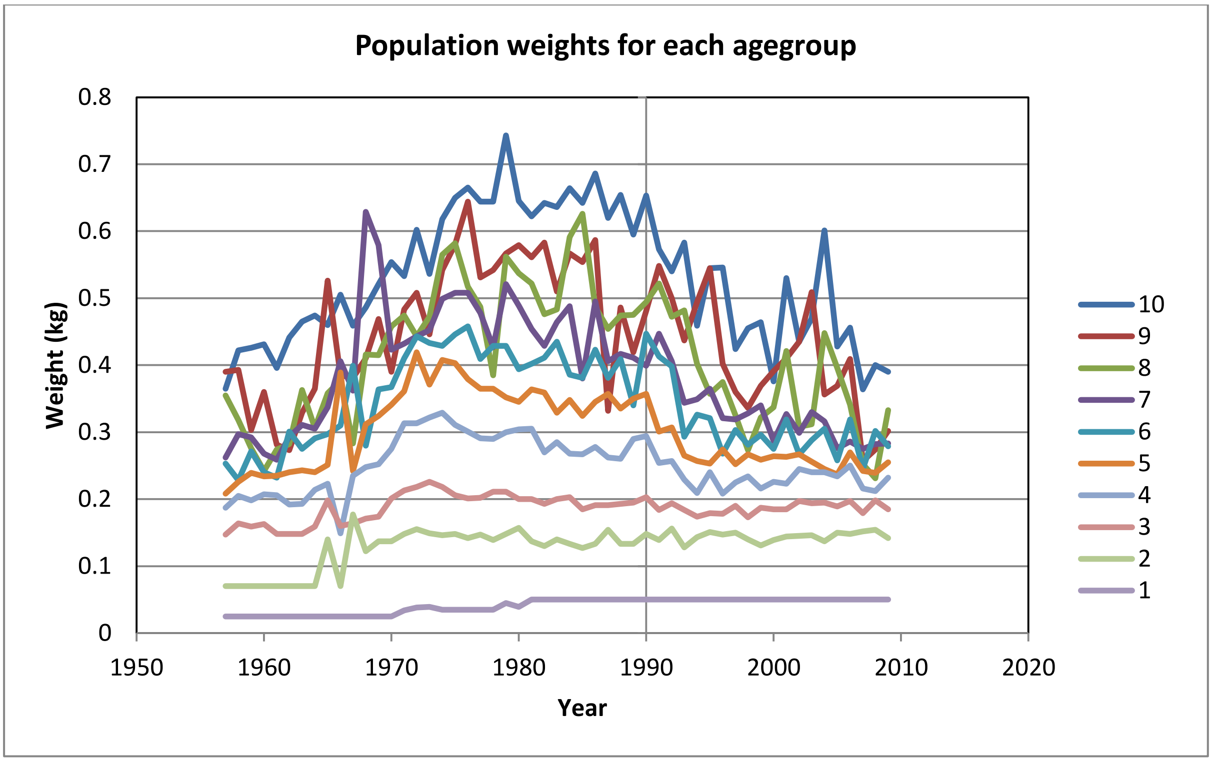


Figure A2.12 Population weights (kg) for Sole in Subarea IV for each age group.