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REPORT OF THE

WORKSHOP ON FLEKSIBEST – AN AGE AND LENGTH BASED ASSESSMENT TOOL

Bergen, Norway
16–19 January 2001

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1 INTRODUCTION

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1.2 Terms of reference

It was decided at the 88th Annual Science Conference in 2000 (C. Res. 2000/2D01) that:

A **Workshop on FLEKSIBEST – an age and length based assessment tool** (WKFLEK) (Chair: Dr. K. Guldbrandsen Frøysa, Norway) will be held in Bergen, Norway from 16-19 January 2001 to:

a) define a protocol and workplan for testing the FLEKSIBEST model based on a review of the model and the results of runs made during and after the AFWG meeting in 2000. These results allow comparison of method performance;

b) enable participants through hands-on exploration of FLEKSIBEST to contribute to the test and further development of the method;

c) discuss the interpretation of results from FLEKSIBEST.

WKFLEK will report by 26 January 2001 for the attention of the Resource Management Committee and ACFM.

1.3 Background

In 1997, a research project for constructing a new assessment model for Northeast Arctic cod- FLEKSIBEST- was started at IMR, Bergen, Norway. A workshop on comparison of stock assessment model strategies, with application to Northeast Arctic cod, was held in December 1998 (Pennington, 1999). FLEKSIBEST was a main topic at that workshop. This model has been run as an auxiliary model for Northeast Arctic cod in addition to the 'standard' XSA assessment at the last two ordinary meetings of the ICES Arctic Fisheries Working Group (AFWG) (ICES CM 2000/ACFM:3; ICES CM 2001/ACFM:2), and will also be used at the next meeting of the AFWG (April/May 2001). As FLEKSIBEST is a model with a more complicated structure (age and length based) than assessment models presently in use by ICES Working Groups, it was found appropriate to arrange a workshop. The purpose of the Workshop was to contribute to the evaluation, testing and further development of the model.

1.4 Structure of the report

Relevant background information is given in Sections 2 and 3. Section 2 deals with existing assessment models and with some problems which have been encountered in the assessment of Northeast Arctic cod. Section 3 gives a description of FLEKSIBEST (model and data). In Section 4 the results of hands-on exploration of FLEKSIBEST (ToR b) are described. The interpretation of the results from actual FLEKSIBEST runs (ToR c) are also considered in this section. A more general discussion of how to interpret results from a model of this kind is given in Sections 5.1-5.4, and guidelines for future work are given in Section 6. These sections address the workplan request in ToR a). During the meeting, this request was redefined from definition of a workplan for testing of FLEKSIBEST to definition of tools and approaches for analysis of models of this kind. How a model (e.g. FLEKSIBEST) can be certified for use as an ICES stock assessment tool (ToR a) is described in Section 5.5.

1.5 Terminology

The word 'model' is used in three ways in the report:

a) To describe a framework or toolbox for stock assessment (e.g. FLEKSIBEST);
b) To describe a model in which sub-models for biological and fisheries processes are chosen, but without a set-up for which parameters to estimate and which to fix;
c) An actual realisation of a model, with a data set and a choice of which parameters to fix and which to estimate.

2 ASSESSMENT MODELS

2.1 Existing models

Models applied to fish stock assessment may be structured in many ways, from biomass-based models to models where the population is structured by some or all of the variables age, length, sex and area. Here we will briefly mention some models that are structured by age and/or length.

The existing age-structured models used for fish stock assessment fall into two groups:

a) VPA-type models where the catch-at-age is assumed to be exact, e.g. XSA (Shepherd, 1999) and ADAPT (Gavaris, 1988). In such models the stock abundance in numbers and the fishing mortalities are derived directly from catches-at-age. Relationships between abundance indices and stock abundance are used to calibrate such models.

b) Statistical catch-at-age models. The characteristic feature of these models is that a self-contained population model is fitted to the data (catches, surveys), and that the catch-at-age is not assumed to be exact. Examples of such models are CAGEAN (Fournier and Archibald, 1982, Deriso et al., 1985) and ICA (Patterson and Melvin, 1996).

Length-based models are often used for species which are difficult to age. An example is the length-based assessment of the Northern shelf anglerfish conducted for the first time at the 2000 meeting of the Northern Shelf WG (ICES CM 2001/ACFM:01), as a comparison to the simple separable catch-at-age assessment, which had previously been used. The assessment used the size transition matrix model ideas of Sullivan *et al.* (1990).

Simulation models that are age- and length-structured have been formulated e.g. for boreal multispecies systems; MULTSPEC (Bogstad et al., 1997); BORMICON (Stefánsson and Pálsson, 1997; 1998). These were not made specifically for making assessments of the present stock size. However, the BORMICON model has been used in the assessment of Golden redfish (*Sebastes marinus*) in the Northwest Atlantic (ICES C.M. 2000/ACFM:15).

Age- and length structured models where the length structure is described by a probability distribution have also been presented (Deriso and Parma, 1988; DeLeo and Gatto, 1995).

2.2 Assessment of Northeast Arctic Cod

Northeast Arctic Cod has been assessed using the Extended Survivors Analysis (XSA) model for the past several years.

The assessment of this stock, however, has proven to be quite problematic over a considerable period for a variety of reasons. In particular, most assessments have underestimated fishing mortality and overestimated population size in the most recent year of the assessment data. Several particular concerns have been raised as follows:

1) The assumption of stock size dependence up to a certain age in survey indices has had a substantial impact on the results in many assessments. In the XSA a stock size dependence option is available, however, it has to be applied for the same age groups over all fleets used for VPA calibration. The AFWG has considered this to be a limitation as to how well the survey calibration data could be utilised.

2) There has been doubt about the reliability of the catch statistics, particularly with respect to discarding and under-reporting, which indicates that there is a need for alternative models, which do not assume that the catch data are correct.

3) In some years rapid changes in growth and maturation contributed strongly to “biased” predictions of stock size and catches.

4) Including cannibalism in the XSA assessment has required a laborious and time-consuming procedure of manual iterations.

5) Concerns about substantial influence from low and noisy values (due to log-transformation in XSA) have also been raised, however, this problem is not unique to NEA cod.

It is recognised that the main problems plaguing the assessment of NEA Cod relate both to the model formulation used and to the data and how they are interpreted. It is evident that there are periodic changes in the relationship between surveys and model-based stock estimates, which also could be associated with:

- Uncertain catch statistics;

- Changes in survey methodology;

- Unaccounted mortality due to sea mammal consumption of cod, which is indicated to vary with varying capelin stock abundance.

It was considered, therefore, that development of a more flexible assessment tool such as FLEKSIBEST would be helpful in addressing some of the concerns identified above.

3 FLEKSIBEST

3.1 Description

FLEKSIBEST (Frøysa *et al*., 2001) is a computer program for an age- and length-structured fish stock assessment model. It has been applied to Northeast Arctic cod. It is essentially an age- and length-structured version of the ‘statistical catch-at-age analysis’ class of models. Length structure is included because most population dynamics processes are related to the size rather than the age of fish. For Northeast Arctic cod and many other fish stocks in boreal systems, age is not a good proxy for size. Such stocks experience large inter-annual variation in growth and thus in size-at-age (Mehl and Sunnanå, 1991).

In FLEKSIBEST, the immature and mature stock is modelled separately. Growth, maturation, natural mortality and fishing mortality are modelled as length-dependent processes. A model for predation mortality due to cannibalism is included. Each fleet has its own separate length-dependent selection. Annual recruitments are model parameters, which are estimated.

The abundance of a cohort in the first year of the time period also has to be estimated, together with annual fishing mortalities and survey catchabilities. Parameters describing annual growth rate, maturation fleet selection and cannibalism may either be determined externally or estimated by the model.

The model is fit to the data (survey abundance indices, commercial catch data, stomach content data from surveys) by minimising the discrepancy between modelled and observed values, based on likelihood-type approaches.

FLEKSIBEST is based on the Icelandic multi-species, multi-area model BORMICON (Stefánsson and Pálsson, 1997; 1998) and shares much of the same program code and functionality. The main modifications are the change from a multi-species, multi-area model to a single-species, single-area application. FLEKSIBEST and its associated programs run under Unix and Linux. Since Linux is freely available for PC and Macintosh computers the software will run on almost all computer platforms, and can run within Windows using a Unix emulation program.

3.2 Data used

FLEKSIBEST uses survey abundance indices, data from commercial catches and stomach content data from scientific surveys. Commercial CPUE data are not used at present, but will fit into the model. The data used are calculated in the same way as those used in the standard age-based assessment, but they are not aggregated over length groups before being used by the model. The model can be run on any age range desired. The runs presented in this report cover the age range 3-12+. The model was run over the time period 1983 (first quarter)-2000 (first quarter), which is the period when data are currently available.

3.2.1 Survey abundance indices

FLEKSIBEST uses abundance indices by age and length from the following surveys:

1. Norwegian winter (February) survey in the Barents Sea – bottom trawl indices (Jakobsen et al., 1997);

2. Norwegian winter (February) survey in the Barents Sea – acoustic indices (Jakobsen et al., 1997);

3. Lofoten acoustic survey (March/April) (Korsbrekke, 1997);

4. Russian autumn (October/December) bottom trawl survey in the Barents Sea (Lepesevich and Shevelev, 1997);

5. Norwegian summer (July/August) survey in the Barents Sea – bottom trawl indices (Aglen, 1999).

Also, annual weight-at-length data from surveys 1 and 3 have been used in calculations of biomass, but not in fitting model to data.

The age and length range for which the survey data are used in the model runs presented in Chapter 4 are described in the text table below. The stock(s) each survey is assumed to cover (immature/mature/both) is also given, together with the time period for which data are available. Data are given on 5 cm length groups:

Survey	Age (years)	Length (cm)	Time period	Stock covered
1	3-10	20-90	1983-1993, 1994-2000	Immature
2	3-10	20-90	1983-1993, 1994-2000	Immature
3	5-12	55-110	1985-2000	Mature
4	3-12	5-110	1983-1999	Both
5	3-12	5-110	1995-1999	Both

The time series for surveys 1 and 2 are split in two periods (1983-1993, 1994-2000) because of the change of gear and increase in area coverage in 1994 (Jakobsen *et al*., 1997). The indices from surveys 1 and 2 (carried out at the same time) are correlated. One of the reasons for this is that in general the same length and age samples are used in calculation of both indices.

Much work has been done on attempting to quantify the uncertainty of the Norwegian survey estimates. One example of quantification of uncertainty, which could be utilised in FLEKSIBEST, is from the Norwegian bottom trawl winter survey (1), where the coefficient of variation for the number of fish in each 5 cm length group is given in the survey report (Mehl, 1999).

3.2.2 Commercial catch data

The catch in numbers-at-age and length for each year and quarter for the following fleets is available:

Norway: Danish seine, gillnet, handline, longline and trawl;
Russia: trawl.

These fleets account for 85-90 % of the reported catch. From third countries, catch in tonnes, but not age-length data, are currently available.

Data for all fleets are given on 5 cm length groups for ages 3-12+ and length groups 5-135 cm. Data are available for 1983 and 1985-1999. All fleets are assumed to fish both on immature and mature fish.

Work on quantification of uncertainty in catch data is in progress, but no results are available yet.

3.2.3 Stomach content data

Stomach content data for cod are collected annually on Norwegian and Russian surveys for demersal fish. The methodology is described in Mehl and Yaragina (1992). In order to compare data on the abundance of cod prey in cod stomachs with the mortality induced by the cannibalism model in FLEKSIBEST, a gastric evacuation rate model (dos Santos and Jobling, 1995) was combined with the stomach content data. The consumption (kg/time step) of cod by cod (cannibalism), by prey length group and predator age group, was then calculated in the same way as in Bogstad and Mehl (1997). No attempts have been made to quantify the uncertainty in the stomach content data or the calculated consumption.

Data are available for 1984-1999, on predator age groups 3-9+ and on 5 or 10 cm wide prey length groups. The data have been calculated on a half-year basis, but are for this purpose distributed evenly on the two quarters within a half-year.

In the model it is assumed that both mature and immature cod are predators on immature cod.

3.2.4 Biomass of alternative prey

The model for cannibalism in FLEKSIBEST takes into account the biomass of alternative prey. Capelin is the main prey item for cod (Bogstad and Mehl, 1997), and quarterly abundance estimates of capelin biomass based on annual acoustic abundance estimates (Gjøsæter *et al.* 1998) and assumptions about growth, natural mortality and fishing mortality are used to represent the abundance of alternative prey.

3.3 Fitting model to data

Within FLEKSIBEST, there is an age-length structured model and three separate sources of data, which are formally linked through an objective function. The objective function must minimise the difference between model predictions and observed data.

Data sources

The data sources used in FLEKSIBEST are:

- commercial catch data;
- survey data; and
- stomach content data.

There may be several fishing fleets and surveys, but it is assumed that all the data sources are independent. The three sources of data are used for parameter estimation within FLEKSIBEST. The model data are age-length structured data from commercial catches and surveys, and calculated consumption derived from stomach content data (Section 3.2.3).

Objective function

An objective function is defined to compare observed and modelled values. The overall objective function is a sum of partial objective functions, each representing the comparison of a certain data set (commercial catch, survey, consumption), and there is limited flexibility in the choice of what to include, and which parameters to optimise and constrain. A component of the objective function is also employed to prescribe upper and lower bounds on variables to be estimated. Parameters exceeding their pre-set bounds contribute a very large value to this component.

A limited selection of objective functions (Pearson, Gamma), and of aggregation levels at which model and data are compared, are currently implemented. The choice of objective function can be critical to the solutions obtained.

Common practise is to derive objective functions as likelihood functions based upon distribution assumptions. Formulation of the objective function as a likelihood function has the additional benefit of producing measures of precision (dispersion, asymptotic standard errors) for optimised (unconstrained) parameters. However, estimates of precision are not yet implemented within FLEKSIBEST.

Initial conditions

Typically, one may want to estimate 150-200 parameters and treat as fixed 200-300 parameters. No documentation is available on the choice of either suitable starting values to adopt or bounds to impose on the solution space. The selection of initial parameter values will be time consuming and may be prohibitive for some applications. There is no simple basis for the choice of either the weighting of observations or the weighting of components within the objective function. The specification of relative weights cannot be accomplished automatically and the results can be sensitive to the values for such weights.

Optimisation

Currently two minimisation algorithms are implemented within the program – a direct search algorithm and simulated annealing, although the latter is currently not used in FLEKSIBEST. The numerical routine used for optimisation of the objective function is based upon the direct search algorithm of Hooke and Jeeves (1961). This has the advantage of being robust but is generally slow for large numbers of parameters.

The following suggestions were made during the sub-group discussions:

- The data available for assessment purposes and the range of plausible relationships between these data and the quantities included in the model need to be specified.

- It was suggested that the model should be written to be formally independent of the data. Currently, the model may incorporate assumptions based on *external* data (e.g. growth rates), ideally these should be subject to rigorous examination.

- Alternative objective functions and optimisation routines will be needed. There appears to be a lack of statistical rigour in the choices implemented for the example considered during the Workshop.

- Uncertainty estimates are not provided at present but techniques and algorithms to provide these will be needed in the future.

- Measures of goodness-of-fit need to be identified for components of the model. In addition, diagnostics need to be provided for components within the objective function.

These issues are currently being addressed within a project entitled: *Development of structurally detailed statistically testable models of marine populations* (DST^2). This is a four-year funded project under the EU Framework V Programme (QLRT-1999-01609), which started in February 2000. It is a collaborative initiative between eight partners - MRI, Iceland; IMR, Norway; DIFRES, Denmark; SCUI, Iceland; UiB, Norway; FRS, UK(Scotland); CEFAS, UK(England & Wales); and IFREMER, France.

3.4 Discussion of model assumptions.

The assumptions made within the FLEKSIBEST initial run for the Northeast Arctic cod were examined. These fall into two categories related to models that describe the dynamics of the stock and those for the dynamics of the fishery. The Workshop reviewed the structure of the formulations and the constraining assumptions but could not verify them. The diagnostics produced by FLEKSIBEST are currently insufficient to allow an evaluation of the precision of the numerical estimates at the "converged" solutions, the correlation between parameters or the testing of departures from the assumptions.

Exploratory runs carried out at the Workshop (Section 4) highlighted the sensitivity of the model and absence of analytical diagnostics for model evaluation. It was noted that relatively minor variations of the starting values provided for the estimated parameters, resulted in relatively large variations in the final "converged" parameter estimates. This was achieved with only minor differences in the objective function value. This relatively simple sensitivity analysis suggests that the numerically estimated solution is not well defined and consequently the parameter values are poorly determined.

Concerns were raised that the initial model structure for the Northeast Arctic cod may be poorly parameterised and that externally fitted, constrained parameters may have a greater influence on the final solution than many of those included within the minimisation. The sensitivity of the initial model parameter estimates to one such parameter, the coefficient of consumption, was examined. When estimated by the program, the model estimated value was half of the constraint value and there was a substantial increase in the estimated catch biomass in the most recent years. The run confirms the influence of the externally estimated consumption parameter and indicates that it should be included within the model formulation and estimated within an extension of the objective function.

The Workshop noted from the FLEKSIBEST results presented in the AFWG Report (ICES CM 2001/ACFM:02, Figures 3.10 and 3.12d), that catch numbers at age in each year of the model fit appear to be well estimated; this contrasts with an over-estimation of catch biomass. The Workshop suggested that the estimated and observed values of weight at length be examined in order to validate the assumptions made within the growth formulations.

The initial model formulation for the Northeast Arctic cod selection-at-length was discussed and considered to be too restrictive for the modelling of the fishing fleets. Concerns were raised that a flat-topped selection pattern was being imposed on the fleet selection and a more flexible formulation, such as the "bell-shaped" model, should be examined to allow for the possibility of a decline in selection at longer lengths.

In addition the following suggestions were made:

- That the diagnostics for the model should be given a high priority so that model and assumption testing and evaluation can be carried out (Ref. Section 5).

- Recruitment is provided only as the number of recruits. There is no process model for either recruitment or the development of early life-history stages. Such processes should be investigated.

- A link between spawning stock biomass and recruitment needs to be investigated.

4 EXPLORATORY RUNS

A few exploratory runs were made. Some selected results were presented and discussed. This is summarized below.

Initial run

Appendix 1 specifies parameters, their starting values, optimization switch (1=”on”, 0=”off”), and the result of the optimization. Tables 4.1-13 show the resulting stock estimates.

A useful evaluation of the estimated parameters and overall results has to include a close inspection of how modelled values compare to the observations, such as survey estimates by length or age, each fleets’ catch by length or age, and consumption by length or age. Such comparisons should particularly aim to detect possible violations of the model assumptions.

Since programs presenting convenient comparisons were not easily available, just two examples of detailed comparisons were made; modelled and observed survey values by length for the Russian bottom trawl survey and for the Norwegian bottom trawl winter survey.

A poor fit was observed for the Russian survey. For this survey the estimated value of L50 in the selection function was equal to the lower bound specified. The patterns shown in Figure 4.1 illustrate that for this survey the selection for small fish is estimated to be too high by the model. By accident the initial value had been set at the lower bound. It was not further explored whether a more realistic starting value would change the result. Figure 4.2 shows a reasonable pattern for the Norwegian bottom trawl winter survey, but some variation between years is evident.

Initial run with altered starting values

To test whether the result could depend on parameter starting values, the starting values were changed for 15 of the parameters to be estimated (Appendix 2). Those parameters were: annual growth for the years 1983-1987, number of immature 3-year-olds in start-year, recruitment in 1986, 1989, 1993 and 1994, and mean length of recruits in 1985-1989.

The program was run to the chosen convergence criteria. The final likelihood value for this run was 6 647 422, compared to 7 105 477 for the initial run.

Some changes in final results were observed (Figures 4.3-6). This was most pronounced for the spawning stock biomass, less for catches and total biomass, and rather marginal changes were observed for fishing mortality.

Initial run without optimization of yearly growth rate

Yearly growth rates were set as estimated by the initial run and a new run was made with all other settings as in the initial run. The results (Figures 4.7-10) show a small increase in recruitment over the whole time series, some increase in catch and biomass before 1995 and some differences in F, variable in time.

Initial run + optimizing consumption

The alpha in the consumption equation (cann_alpha) was added as the 177th variable in a run and results were compared to results from the initial run with 176 variables. The final likelihood value for this run was 6 934 705. In the initial run the value for alpha was fixed at 7.0e-06 while the value reached after optimizing was reduced to 2.4178e-06. This resulted in a 10-30% increase in spawning stock biomass (SSB) in the 90s (Figure 4.11). Also catches increase especially in 1994 (Figure 4.12). The M2 (predation mortality) is reduced to 50% of the value of the initial run for 3 and 4-year-old cod (Figure 4.13).

5 TESTING AND EVALUATING OF FLEKSIBEST

5.1 Introduction

In this section a certain number of issues related to testing and evaluating parameter estimates obtained with FLEKSIBEST are raised. Methods for investigating the success of the estimation procedure are dealt with. This includes the exploration of the sensitivity of final results to starting values. Some diagnostics for assessing the model fit for given model and data sets are proposed, and sensitivity of estimates to a change in values of fixed parameters and model misspecification are considered.

These investigations are for a given model formulation, which includes the actual functional forms as well as what parameters are fixed and which ones are estimated within FLEKSIBEST. Strategies for model building are considered in the following section.

5.2 Model building

Model building aims at identifying models that are parsimonious in their number of parameters. This may be achieved by systematically adding variables to a minimal basic starting model, and identifying those which give the greatest improvement in model accuracy, and allowing the rejection of redundant or minimally useful components. In a complex model such as FLEKSIBEST the number of possible permutations of model components is extremely large, therefore a method is needed to rapidly assess the potential contribution of different model components, and easily identify which ones are worth considering further.

The model produces values for objective functions comparing the output of the model to various data sets, and an overall summary objective score. These objective values provide an ideal tool for a first assessment of the utility of different combinations of model components. As an example Table 5.1 indicates the objective scores for a simple single-species, single-area BORMICON model, and the improvement obtained by allowing different parameters, mean length of recruits, growth rate *k* in von Bertalanffy growth function, and fleet selectivity curve, to vary on an annual basis or to introduce variability of the length of recruits around the mean value. Each component is shown as a percentage of the objective value of the original model run. It can be easily seen that either allowing for annual changes in mean length of recruited fish, or growth rates, produces a noticeable (about 12%) improvement to the model fit, while introducing variability in length of recruits produces a much smaller (5%) improvement. This can be extended to combinations of different variables, and should lead to a rapid elimination of redundant terms. FLEKSIBEST is a derivative of the BORMICON model, and thus this approach should translate well between the two models.

Analysis of different objective components can also be used to investigate model behaviour, identifying areas of the model which are performing well, and which are doing less well. In the example below the length distribution in the catch behaves differently from the other components. This highlights a possible problem in the model formulation for commercial catches.

It is suggested that an approach such as this should be employed as a first step in identifying which model components provide a significant contribution to the process description, and as an investigative tool in understanding and exploring the model behaviour.

Table 5.1. Changes (in %) in the objective components due to different changes in the model formulation. Results were obtained using BORMICON for a haddock example.

Component	Annual recruit length % of ORIG	Annual growth rate % of ORIG	Variability in recruit lengths % of ORIG	Catch selectivity % of ORIG
Overall Objective score	0,90	0,91	0,98	0,96
% of original value	**88,04**	**88,50**	**95,37**	**93,82**
mean length in survey	76,16	63,80	99,46	101,47
mean length in catch	78,66	74,47	98,94	94,11
Length distribution in survey	78,13	98,41	87,09	98,92
Length distribution in catch	101,77	100,59	100,42	82,48
age-length key: survey	76,72	77,25	96,52	101,57
age-length key: catch	93,27	92,96	99,06	101,26
Survey index: 10cm	41,22	120,50	2,63	101,94
Survey index: 15cm	80,80	71,05	95,70	102,70
Survey index: 20cm	80,38	87,73	100,96	99,02
Survey index: 25-45cm	74,77	58,22	94,23	98,58
Survey index: 50-60cm	105,66	84,05	99,17	105,59
Survey index: 65-75cm	98,09	114,02	101,31	89,20
Nvpa	60,10	68,78	99,45	81,07

5.3 Evaluating model fit for selected model

For a particular model, it is important to be able to assess whether this chosen model is appropriate given the observed data and assumptions, e.g. fixed parameters and boundary constraints. The main objective is therefore to detect any systematic failures or weaknesses of the model and its assumptions. This is an important stage in the testing of any model, but becomes a significant task when the model is as complex as that used in FLEKSIBEST. Visual diagnostics may be useful as a first step, but should be followed up by a more rigorous numerical analysis. The group proposed the following suggestions as a first approach.

After convergence, the routine outputs the number of steps required by the search algorithm to converge on the optimum solution as well as the initial and final values of the objective function. A further useful output would be a list of those parameter estimates that lie on their boundary and a list of names of those parameters. Parameters lying on their boundaries may indicate incorrect model assumptions or parameter constraints.

As a first step in evaluating the fit of a particular model, a visual comparison of predicted and observed quantities (those used in the objective function) should be conducted. In the case of a FLEKSIBEST run, the following data should be checked by quarter and year:

- catch (in numbers) by fleet vs length

- catch (in numbers) by fleet vs age

- survey indices (in numbers) by survey type vs length
- survey indices (in numbers) by survey type vs age
- consumption by age of predator for length of prey.

The plots suggested above may be useful in helping decide where further investigations could be concentrated, but a more formal analysis should be conducted to detect where any systematic errors occur. Residuals from all components in the objective function should be analysed (by ANOVA, for example) to detect the effects of the type of data (e.g. survey), age, length groups, years and quarters on these residuals. Any such effects might indicate the part of the model, which gives systematically erroneous estimates.

Further residual plots should be used to check the validity of assumptions. For example, checking whether any trend can be detected in residuals (plot of residuals vs. time if the model assumes a particular parameter to be constant over time).

Data that is external to the objective function could also be compared with estimates of these variables obtained from the model. For example:

- growth rates by length group and year for mature and immature individuals
- maturity at length by year
- mean length in surveys per year, in catch per year, per age and year and fleet
- mean weight at age in surveys per year
- mean weight at length in surveys per year.

An essential component of model evaluation is the consideration of the variance-covariance matrix in order to identify which parameters are ill-defined.

In FLEKSIBEST, the variance-covariance matrix will have large dimensions, which makes a visual approach for studying them virtually impossible. Therefore some other analyses of these matrices might be carried out. One example would be lists of highly correlated parameters and badly estimated parameters (those with high variance).

5.4 Sensitivity analysis

All parameter estimates are conditional on the model formulation and the values of fixed parameters. For assessing the effect of the chosen fixed parameter values and model formulation, sensitivity analyses should be carried out. In the following an outline is given how the sensitivity of parameter estimates to fixed parameter values can be investigated using simulated data. A similar approach can be used for real data.

For any given model with a set of fixed parameters and the simulated data (population numbers, catches, survey indices, stomach data, etc.), all fixed parameters have to be varied in a systematic way. A factorial design is most suited for this. Given there are a large number of fixed parameters, say *nf*, those most influential have to be identified in order to reduce the task to a manageable size. The different steps involved in the analysis would be: i) to create *g* groups of independent parameters making sure all important parameters are included, ii) carry out estimation varying fixed parameters one group at a time (for example +10% and -10% of original values), iii) analyse estimated parameter matrix (*nf* x *g*) and estimated population numbers at age and length by time matrix. Statistical analysis of the results matrices should lead to identification of the important parameter groups and to a quantification of the associated changes in parameter estimates. The sensitivity of population estimates to fixed parameter values is also obtained.

Robustness of parameter estimates to violations of model assumptions or errors in the data can be investigated in a similar manner. For these investigations the simulated data has to come from a model that is different from the model used for estimation.

5.5 Certification of ICES stock assessment tools

If FLEKSIBEST is to be a candidate for an ICES stock assessment tool, then the program needs to be certified and thoroughly tested.

Any analytical software used by ICES assessment working groups has to undergo a defined testing process in order to ensure quality and efficiency (ICES CM 1999/ACFM:25, working document ACFM May 2000, Certification of software used for assessment purposes). Other tools will only be used if the standard library does not provide the necessary method. New programs must be judged against a number of criteria to gauge their suitability for adoption as standard assessment software. It will be necessary to ensure that new software tools as well as the methods they are based on are adequately tested. It is desirable that the testing includes some form of Monte Carlo testing, e. g., using simulated data with known error distributions to verify that the program returns unbiased estimates of the population parameters (ICES CM 1999/ACFM:25). Standardisation of inputs and outputs are part of making a tool suitable for routine ICES stock assessments. In addition, in order to standardise the comparison of methods, the following list has been proposed as a minimum requirement (Patterson, 2000):

- Robustness of assessments to alternative assumptions or data series
- Parameter uncertainty, possibly as confidence intervals
- Illustration of conflicts in data series.

The Workshop did not discuss whether the standard library of assessment models available at ICES provides the necessary method for assessment of Northeast Arctic cod.

6 FURTHER WORK

6.1 Northeast Arctic cod application

FLEKSIBEST is designed as a single-species application for Northeast Arctic cod. Some of the fishery and stock characteristics are in favour of using a single-species model, but there are a number of multispecies issues, which address the use of more integrated assessment models.

6.1.1 Stock components

For assessment the Northeast Arctic cod population in ICES areas I and II is at present defined as a single stock unit. This seems to be sufficient for single species assessment for the time being, but on the other hand there are concerns regarding the relationships between various stock components in the area. For assessment purposes stock boundaries should be clearly defined, but at present the extent of intermixing of various cod stock components is largely unclear.

6.1.2 Fishing fleets

The fishery for Northeast Arctic cod is conducted both by an international trawler fleet operating in offshore waters and by vessels using gillnets, long lines, hand lines, and Danish seine operating both offshore and in the coastal areas. Fishing fleets provide important input data to FLEKSIBEST. However, caution is advised in how to aggregate fishing fleet information for the modelling purposes, in particular because the operation of the fleets may exploit various stock components in different quarters of the year, depending on spatial and temporal fish distribution patterns.

6.1.3 Ecosystem aspects to be considered in the assessments

Considerable effort has been devoted to investigating multispecies interactions in the Northeast Arctic. Some of these investigations have reached the stage where some quantitative results are available for use in assessments. When making a choice to use either a single-species model like FLEKSIBEST or a multispecies model like BORMICON for Northeast Arctic cod stock assessment, the following matters should be considered:

The growth of cod depends on the availability of prey, and variability in cod growth can significantly impact the fishery.

The timing of cod spawning migrations is influenced by the presence of spawning herring in the relevant area.

The annual consumption of herring, capelin, and cod by marine mammals has been estimated to be in the order of 1.5-2.0 million t.

The recent estimate of total annual food consumption of Barents Sea harp seals has been estimated to be in the range of about 3.3-5.0 million t (ICES C.M. 2001/ACFM:08).

If capelin was abundant, the total harp seal consumption was estimated to be about 3.3 million t, of which capelin was approximately 800 000 t, polar cod 600 000 t, herring about 200 000 t and Atlantic cod 100 000 t.

- A low capelin stock in the Barents Sea (as in 1993-1996) led to switches in seal diet composition and they consumed approximately 870 000 t of polar cod, other cod fishes (mainly Atlantic cod) about 360 000 t, and herring about 390 000 t.
- The composition and distribution of species in the Barents Sea is dependent on the position of the polar front which separates warm and salty Atlantic waters from colder and fresher waters of Arctic origin.
- Variation in the recruitment of cod and capelin, for example, is associated with the changes in the influx of Atlantic waters to the large areas of the Barents Sea shelf.

6.2 FLEKSIBEST program

6.2.1 Issues to be addressed in further work with FLEKSIBEST

This is a summary of suggestions made in Sections 3, 4 and 5.

- Guidelines for how to choose the initial parameter values and parameter bounds.
- Guidelines for how to weight the different terms in the objective function.
- Exploration of objective functions and optimisation routines is needed.
- A statistical justification for the choices of objective function must be given.
- Uncertainty estimates need to be provided.
- Measures of goodness-of-fit and diagnostics need to be provided for components within the objective function.
- Diagnostic tools for comparisons of modelled and observed data, both observed data used in the objective function and observations not used directly in the objective function, e.g. mean length-at-age.
- Ability to rapidly assess the potential contributions of different model components to the objective function.
- Making a minimal basic starting model to facilitate model building.
- A summary file on the optimisation, giving the initial and final values of the objective function, a list of the parameters that reached their boundary value (and the value) and the convergence criteria.
- Tools for residual analysis and residual plots must be provided.
- Sensitivity tests with respect to fixed parameters.
- Test of the robustness of parameter estimation results with respect to the initial parameter values.

6.2.2 Optimisation algorithm issues

The efficiency and success of the numerical optimisation algorithm should also be further tested. At present the optimisation is carried out using a direct search algorithm (Hooke and Jeeves, 1961), but other algorithms could be implemented, the code already allows for the implementation of simulated annealing. By using a data set which has been simulated and therefore has known properties, the features of these algorithms can be further investigated. In theory, refitting the model to the simulated data should result in the same parameter values. Tests could be carried out to investigate if, and after how many iterations, the expected parameter values are obtained if, for example, the parameters to be optimised are given different starting values or if the convergence criteria is altered. A short summary file giving the number of steps required in the routine, initial and final values of the objective function and convergence criteria would be a useful standard output.

6.3 Practical concerns for the use of FLEKSIBEST

6.3.1 Introduction

A distinction needs to be drawn between the FLEKSIBEST modelling program itself and the user interface for running the program and interpreting the results. Separate programs can be created to ease the configuration and running of FLEKSIBEST, and to facilitate the interpretation of model results and formulation. These accessory programs are of considerable importance in influencing the practical value of the system. Some work has already been done in developing these programs, but more is needed to ensure the maximum utility of FLEKSIBEST.

6.3.2 Configuring and running the program

FLEKSIBEST is a complex and flexible program, and as such can never be entirely straightforward to use. Files need to be constructed to control both the configuration of the model and the datasets used in the objective functions. The format of the control files is logical, but not well documented, and it would be of use to have a clear and concise guide to interpreting and modifying these files. In particular, documentation of any particular model formulation should be included as well as overall documentation of the system. A guide to the selection of initial values and bounds for estimated parameters and values for fixed parameters should also be provided.

Constructing the data files is at present a major challenge. Work is ongoing in the DST^2 project (see Section 3.3) to address this by means of a data warehouse capable of automatically generating the required files from the underlying datasets. This is a major project, and should considerably reduce the effort required to set up a new model.

6.3.3 Results

There is considerable scope for improvements in presentation of the model results, which would drastically increase the utility of the system. A number of diagnostics have been suggested for the model output (Section 5.3) and the details of the optimisation process (Section 6.2), which it would be desirable to produce automatically. Any such outputs must be accessible and fully documented. A further useful utility would allow summary graphs to be produced of any of the model parameters, along with observed data where applicable. A prototype of such a system already exists, and could be extended in flexibility and utility. There is a trade-off here between ease of use and flexibility. A truly easy to use system would only be possible for a specific model formulation, while a more generalised system encompassing all possible model formulations would require more user input at run time. It would be desirable that standard diagnostics would be available for all models, while more detailed outputs may be available for specific models.

6.3.4 Overall ease-of-use issues

The possibility of constructing a single program to incorporate FLEKSIBEST and the ancillary programs, and present them to the user in a single coherent interface should be investigated. The specification of any such system requires careful thought. For development purposes full flexibility is required, however in practical terms many runs will be made on similarly configured models. A simple check that common features of all these runs are properly implemented each time would therefore be useful.

Documentation exists for the BORMICON family of modelling programs in general, however there is a need for documentation of specific examples, both for training purposes and before presenting model results to a formal body (such as ICES). Work is in progress to address this need.

6.3.5 Computing time

The present model formulation requires several hours for an optimisation run on a moderate specification computer, and around one hour for a high specification machine. This is acceptable for a single optimised run, but makes development and testing of the model inconvenient. Run times would inevitably increase further with any change to multi-species or multi–area models. Run times may be decreased by reducing the number of variables, or running the program in parallel over several machines. It has also been noted that the optimisation may get close to the final solution in less than half the total iterations. In this case it may be worth running the model using a coarser convergence criteria – at least for initial diagnostic runs. There is also a possibility that optimisation of parts of the program may result in significant benefits. At present very little work has been done in this area, and further investigations are required.

7 RECOMMENDATIONS

A study group should be convened for four days in early 2002 in Bergen (Chair: Dr Kristin Guldbrandsen Frøysa, Norway) to investigate process model formulations, goodness of fit and model sensitivity in age-length based models, using tools such as FLEKSIBEST.

Suggested terms of reference:

a) Investigate process model formulations, goodness of fit and model sensitivity in age-length based models, using tools such as FLEKSIBEST. The study group should consider specific case studies on ground fish, flatfish and pelagic fish stocks together with simulated datasets with known properties such as ageing errors.

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Table 4.1

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
Total fishing mortality at age
Year        1983    1984    1985
Age
  3       0.0317  0.0461  0.0464
  4       0.1557  0.1334  0.1558
  5       0.3253  0.3249  0.2795
  6       0.5589  0.5089  0.4619
  7       0.7689  0.6905  0.5847
  8       0.7898  0.7962  0.6370
  9       0.7600  0.7781  0.6272
 10       0.7536  0.7326  0.5935
 11       0.7294  0.7134  0.5513
 12+      0.7047  0.6821  0.5212
F 5-10    0.6594  0.6385  0.5306

Total fishing mortality at age
Year        1986    1987    1988    1989    1990    1991    1992
Age
  3       0.0424  0.0395  0.0388  0.0389  0.0398  0.0594  0.0595
  4       0.2046  0.1667  0.1117  0.1099  0.0954  0.1160  0.1211
  5       0.4128  0.4360  0.2761  0.1854  0.1399  0.1806  0.1779
  6       0.5659  0.6656  0.4968  0.2899  0.1668  0.2135  0.2330
  7       0.7168  0.7921  0.6643  0.4053  0.1930  0.2303  0.2555
  8       0.7766  0.8786  0.7538  0.4859  0.2109  0.2441  0.2648
  9       0.7814  0.8960  0.8050  0.5199  0.2169  0.2502  0.2699
 10       0.7569  0.8873  0.8042  0.5253  0.2168  0.2495  0.2693
 11       0.7321  0.8670  0.7848  0.5104  0.2130  0.2463  0.2652
 12+      0.7015  0.8493  0.7446  0.4695  0.2062  0.2383  0.2582
F 5-10    0.6684  0.7593  0.6334  0.4020  0.1907  0.2280  0.2451

Total fishing mortality at age
Year        1993    1994    1995    1996    1997    1998    1999   1997-1999
Age
  3       0.0259  0.0245  0.0300  0.0279  0.0425  0.0529  0.0274      0.0409
  4       0.1114  0.1334  0.1421  0.1611  0.2076  0.2699  0.1872      0.2216
  5       0.1801  0.2989  0.3682  0.3708  0.4590  0.5297  0.4326      0.4738
  6       0.2340  0.3929  0.5673  0.5861  0.6600  0.7422  0.6123      0.6715
  7       0.2860  0.4538  0.6744  0.7217  0.8120  0.8694  0.7489      0.8101
  8       0.3054  0.5052  0.7367  0.7814  0.8777  0.9310  0.8180      0.8756
  9       0.3119  0.5169  0.7795  0.8025  0.8918  0.9364  0.8322      0.8868
 10       0.3135  0.5176  0.7763  0.8047  0.8830  0.9274  0.8175      0.8760
 11       0.3091  0.5129  0.7649  0.7897  0.8590  0.9125  0.8017      0.8577
 12+      0.2995  0.4991  0.7354  0.7571  0.8151  0.8737  0.7667      0.8185
F 5-10    0.2718  0.4475  0.6504  0.6779  0.7639  0.8227  0.7102
```

Table 4.2

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
Residual natural mortality (M1)
Year         1983    1984    1985
Age
  3       0.2000  0.2000  0.2000
  4       0.2000  0.2000  0.2000
  5       0.2000  0.2000  0.2000
  6       0.2000  0.2000  0.2000
  7       0.2000  0.2000  0.2000
  8       0.2000  0.2000  0.2000
  9       0.2000  0.2000  0.2000
 10       0.2000  0.2000  0.2000
 11       0.2000  0.2000  0.2000
 12+      0.2000  0.2000  0.2000

Residual natural mortality (M1)
Year         1986    1987    1988    1989    1990    1991    1992
Age
  3       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
  4       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
  5       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
  6       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
  7       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
  8       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
  9       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
 10       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
 11       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000
 12+      0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000

Residual natural mortality (M1)
Year         1993    1994    1995    1996    1997    1998    1999   1997-1999
Age
  3       0.2000  0.1999  0.1999  0.2000  0.2000  0.2000  0.2000      0.2000
  4       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
  5       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
  6       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
  7       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
  8       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
  9       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
 10       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
 11       0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
 12+      0.2000  0.2000  0.2000  0.2000  0.2000  0.2000  0.2000      0.2000
Predation mortality (M2)
Year         1983    1984    1985
Age
  3       0.0629  0.0480  0.0640
  4       0.0130  0.0200  0.0216
Predation mortality (M2)
Year         1986    1987    1988    1989    1990    1991    1992
Age
  3       0.1323  0.1535  0.0721  0.0623  0.0736  0.0759  0.1096
  4       0.0344  0.0498  0.0293  0.0174  0.0107  0.0287  0.0420
Predation mortality (M2)
Year         1993    1994    1995    1996    1997    1998    1999   1997-1999
Age
  3       0.2526  0.5035  0.5762  0.3961  0.2429  0.1410  0.0971      0.1603
  4       0.0939  0.1791  0.1965  0.1391  0.1004  0.0586  0.0388      0.0659
```

Table 4.3

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
Stock numbers (thousands) at age by Jan. 1
Year         1983     1984     1985     1986
Age
  3        301259   554294   614201  1164450
  4        159374   224377   413064   450296
  5        104664   110135   157470   282991
  6         51347    61803    64944    96730
  7         43141    24004    30403    33462
  8         43789    16368     9846    13869
  9          6125    16273     6045     4263
 10          1100     2343     6137     2652
 11           500      424      904     2766
 12+          200      278      285      565
Total      711499  1010300  1303299  2052045

Stock numbers (thousands) at age by Jan. 1
Year         1987     1988     1989     1990     1991     1992     1993
Age
  3        355170   262487   195273   312668   714770  1020557  1594098
  4        800621   239767   192334   144490   228533   511145   705550
  5        289877   525787   169794   138585   106364   161775   355032
  6        151654   151112   323289   114618    98360    72419   109132
  7         44802    63479    74983   197505    79322    64990    46879
  8         13371    16577    26695    40893   133261    51562    41188
  9          5223     4545     6378    13439    27110    85456    32375
 10          1599     1748     1667     3110     8884    17344    53553
 11          1018      537      636      801     2022     5604    10664
 12+         1319      812      516      577      914     1884     4711
Total     1664653  1266850   991566   966686  1399539  1992735  2953181

Stock numbers (thousands) at age by Jan. 1
Year         1994     1995     1996     1997     1998     1999     2000
Age
  3       1053674   637471   359254   594498   833419   510360   581379
  4        987981   508730   284306   192403   365858   562018   368907
  5        469822   590732   296032   171973   115519   215194   366090
  6        234630   269239   313155   159217    85981    54385   112573
  7         69814   127235   122580   140569    66620    33259    23989
  8         28796    36050    52767    48583    50987    22825    12854
  9         24836    14216    14095    19757    16529    16450     8244
 10         20099    12398     5413     5190     6655     5321     5870
 11         31319     9527     4594     1961     1732     2139     1913
 12+         9268    19959    11463     6109     2894     1558     1378
Total     2930238  2225557  1463658  1340260  1546193  1423510  1483197
```

Table 4.4

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
Spawning stock biomass (t) at Jan. 1
Year         1983    1984
Age
  4         12342       0
  5         16885   20990
  6         52559   31327
  7        122418   44799
  8        186700   76432
  9         39916  113209
 10         10944   23861
 11          5754    5372
 12+         2654    4300
SSB total  450171  320287

Spawning stock biomass (t) at Jan. 1
Year         1985    1986    1987    1988    1989    1990    1991    1992
Age
  4             0       0       0       0       0       0       0       0
  5         24718   37362   24281   18105    5630   20265   25388   43684
  6         57778   52246   73816   41787   58403   44378   75021   73858
  7         63283   61943   59482   67777   62247  211904  115705  141580
  8         43351   49078   44795   38948   62290  111894  378880  172568
  9         47542   24445   28620   21732   26879   68779  137005  439028
 10         63446   22642   12729   12234   11963   23085   66068  128985
 11         12622   29824   11664    5196    6286    8840   19795   56017
 12+         4882    8058   20039   12700    8826   10120   13937   26013
SSB total  317622  285597  275427  218478  242521  499264  831798 1081732
Spawning stock biomass (t) at Jan. 1
Year         1993    1994    1995    1996    1997    1998    1999    2000
Age
  4             0       0       0       0       0       0       0       0
  5         45854   63899   42430   15390   12501   10354   16815   24409
  6         72316  124439  140304  109084   54758   41220   22881   44464
  7         88663  103506  167519  173629  184034   96744   47133   30349
  8        140161   93188   96626  145405  159890  183256   71814   39213
  9        152894  120921   69586   62804  102023  105359   93776   44356
 10        351441  118910   81516   37114   37294   57444   44279   47964
 11         97396  251152   79325   40990   20262   19568   22593   21327
 12+        60207  103534  228909  145054   97847   55302   25508   21397
SSB total 1008931  979550  906216  729469  668608  569246  344799  273479
```

Table 4.5

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
Total stock biomass (t) at Jan. 1
Year        1983    1984
Age
  3       118841  232972
  4       155878  162811
  5       173698  158154
  6       143073  137173
  7       191366   83165
  8       264968   90544
  9        51120  123195
 10        10944   24688
 11         5754    5372
 12+        2654    4300
Total    1118295 1022373

Total stock biomass (t) at Jan. 1
Year        1985    1986    1987    1988    1989    1990    1991    1992
Age
  3       286279  442478  128848   91947   81158  192244  532198  775993
  4       406385  350962  467118  128673  132441  158031  268506  601613
  5       248881  395824  337463  488209  170409  221447  199455  296584
  6       172997  199544  293518  241444  500564  237440  250053  204256
  7       116083  107956  123890  158543  184876  566428  251005  243092
  8        53856   61641   56837   57833   98829  171179  557816  235173
  9        48958   25960   30600   23897   32201   79475  156326  498845
 10        64285   22771   12892   12465   12349   24159   68492  133684
 11        12622   29824   11664    5196    6286    8840   19795   56017
 12+        4882    8058   20039   12700    8826   10120   13937   26013
Total    1415228 1645017 1482869 1220907 1227937 1669361 2317582 3071270
Total stock biomass (t) at Jan. 1
Year        1993    1994    1995    1996    1997    1998    1999    2000
Age
  3       661935  319805  162967   82930  152424  244343  123240  138439
  4       656687  759546  326741  173224  121155  252648  359588  209976
  5       522879  702858  735368  326429  204503  143092  259684  420289
  6       240682  506329  559681  579247  296518  175565  103631  213043
  7       156866  208946  360116  359517  410495  206142   97700   66951
  8       182247  123003  137560  207915  213925  241906   97083   53506
  9       174464  134669   77226   72940  114584  113892  101353   48685
 10       368364  128078   85536   38649   38997   58938   45099   48772
 11        97396  251152   79325   40990   20262   19568   22593   21327
 12+       60207  103534  228909  145054   97847   55302   25508   21397
Total    3121725 3237922 2753429 2026894 1670711 1511395 1235478 1242386
```

Table 4.6

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
Weight (kg) in catch (Observed)
Year      1983  1985  1986  1987  1988  1989  1990
Age
  1       0.02  0.12  0.09  0.09  0.07  0.05  0.16
  2       0.45  0.33  0.31  0.24  0.32  0.51  0.44
  3       0.84  0.94  0.64  0.51  0.54  0.74  0.83
  4       1.37  1.37  1.27  0.88  0.86  0.96  1.22
  5       2.08  2.01  1.87  1.55  1.31  1.32  1.65
  6       2.86  3.21  2.79  2.32  2.23  1.91  2.23
  7       3.99  4.63  4.49  3.43  3.52  2.93  3.23
  8       5.58  6.04  5.84  5.92  5.34  4.63  4.67
  9       7.76  7.65  6.83  8.59  8.04  7.51  7.30
 10       9.30  9.81  7.68  9.60  9.28  9.12  9.84
 11      11.55 11.80  9.81 12.20 11.46 11.08 13.25
 12+     16.46 14.08 11.17 13.61 15.42 14.95 14.21

Weight (kg) in catch (Observed)
Year      1991  1992  1993  1994  1995  1996  1997  1998  1999   1997-1999
Age
  1       0.12  0.06  0.14  0.04  0.11  0.08  0.10  0.12  0.06      0.09
  2       0.48  0.54  0.49  0.41  0.40  0.31  0.33  0.35  0.33      0.34
  3       1.05  1.17  0.80  0.84  0.81  0.82  0.71  0.69  0.64      0.68
  4       1.45  1.57  1.50  1.30  1.25  1.13  1.06  1.06  1.03      1.05
  5       2.16  2.22  2.16  2.00  1.79  1.63  1.54  1.61  1.49      1.55
  6       2.89  3.11  2.80  2.86  2.57  2.45  2.22  2.28  2.26      2.25
  7       3.74  4.26  4.16  3.21  3.78  3.83  3.41  3.28  3.18      3.29
  8       4.71  5.18  5.55  5.27  4.94  5.81  5.29  4.85  4.30      4.82
  9       6.07  6.13  6.48  6.86  6.14  6.85  7.32  6.89  6.01      6.74
 10       8.80  7.77  7.19  7.60  8.02  8.10  7.83  9.44  6.80      8.03
 11      11.80 10.11  7.99  8.05  8.82  9.51  8.62 10.63 10.83     10.03
 12+     16.61 11.81 11.36 10.02  9.61 11.12 11.42 15.19 14.46     13.69
```

Table 4.7

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
Weight (kg) in catch (Model)
Year      1983  1985  1986  1987  1988  1989  1990
Age
  1        -     -     -     -     -     -     -
  2        -     -     -     -     -     -     -
  3       0.69  0.85  0.63  0.51  0.63  0.83  1.17
  4       1.27  1.40  1.18  0.92  0.95  1.16  1.57
  5       1.87  1.99  1.80  1.49  1.35  1.48  2.08
  6       3.02  2.99  2.45  2.21  2.01  2.01  2.57
  7       4.53  4.01  3.59  3.01  2.90  2.88  3.38
  8       6.34  5.54  4.79  4.51  3.88  4.01  4.63
  9       8.99  7.99  6.46  6.20  5.70  5.20  6.16
 10      10.73  9.84  8.82  8.51  7.70  7.13  7.61
 11      12.55 11.97  9.85 11.84 10.18  8.71  9.62
 12+     14.52 14.06 10.90 14.46 13.66 11.31 11.65

Weight (kg) in catch (Model)
Year      1991  1992  1993  1994  1995  1996  1997  1998  1999   1997-1999
Age
  1        -     -     -     -     -     -     -     -     -         -
  2        -     -     -     -     -     -     -     -     -         -
  3       1.20  1.10  0.76  0.63  0.66  0.63  0.67  0.72  0.57      0.65
  4       1.74  1.56  1.41  1.11  1.03  1.08  1.16  1.17  1.05      1.13
  5       2.39  2.23  1.92  1.81  1.59  1.52  1.71  1.71  1.61      1.68
  6       3.10  3.11  2.66  2.41  2.51  2.31  2.40  2.51  2.37      2.43
  7       3.77  4.01  3.70  3.26  3.32  3.49  3.53  3.57  3.52      3.54
  8       4.82  4.82  4.74  4.55  4.36  4.56  5.08  5.22  4.97      5.09
  9       6.30  6.06  5.66  5.80  5.97  5.87  6.50  7.34  7.02      6.95
 10       7.71  7.73  7.05  6.82  7.41  7.85  8.05  9.10  9.01      8.72
 11       8.72  9.20  9.04  8.55  8.71  9.36 10.11 10.71 10.22     10.34
 12+      9.89  9.86 11.21 11.03 10.79 11.33 11.16 11.70 11.72     11.53
```

Table 4.8

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0

Weight (kg) in stock at Jan. 1
Year      1983  1984  1985  1986  1987  1988  1989  1990  1991
Age
  3       0.39  0.42  0.47  0.38  0.36  0.35  0.42  0.61  0.74
  4       0.98  0.73  0.98  0.78  0.58  0.54  0.69  1.09  1.17
  5       1.66  1.44  1.58  1.40  1.16  0.93  1.00  1.60  1.88
  6       2.79  2.22  2.66  2.06  1.94  1.60  1.55  2.07  2.54
  7       4.44  3.46  3.82  3.23  2.77  2.50  2.47  2.87  3.16
  8       6.05  5.53  5.47  4.44  4.25  3.49  3.70  4.19  4.19
  9       8.35  7.57  8.10  6.09  5.86  5.26  5.05  5.91  5.77
 10       9.95 10.54 10.47  8.59  8.06  7.13  7.41  7.77  7.71
 11      11.51 12.67 13.96 10.78 11.46  9.68  9.88 11.04  9.79
 12+     13.27 15.47 17.13 14.26 15.19 15.64 17.10 17.54 15.25

Weight (kg) in stock at Jan. 1
Year      1992  1993  1994  1995  1996  1997  1998  1999  2000   1997-1999
Age
  3       0.76  0.42  0.30  0.26  0.23  0.26  0.29  0.24  0.24        0.26
  4       1.18  0.93  0.77  0.64  0.61  0.63  0.69  0.64  0.57        0.65
  5       1.83  1.47  1.50  1.24  1.10  1.19  1.24  1.21  1.15        1.21
  6       2.82  2.21  2.16  2.08  1.85  1.86  2.04  1.91  1.89        1.94
  7       3.74  3.35  2.99  2.83  2.93  2.92  3.09  2.94  2.79        2.98
  8       4.56  4.42  4.27  3.82  3.94  4.40  4.74  4.25  4.16        4.47
  9       5.84  5.39  5.42  5.43  5.17  5.80  6.89  6.16  5.91        6.28
 10       7.71  6.88  6.37  6.90  7.14  7.51  8.86  8.48  8.31        8.28
 11      10.00  9.13  8.02  8.33  8.92 10.33 11.30 10.56 11.15       10.73
 12+     13.81 12.78 11.17 11.47 12.65 16.02 19.11 16.37 15.53       17.17
```

Table 4.9

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0

Proportion mature at age
Year      1983  1984  1985  1986  1987  1988  1989  1990  1991
Age
  3      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
  4      0.079 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
  5      0.097 0.133 0.099 0.094 0.072 0.037 0.033 0.092 0.127
  6      0.367 0.228 0.334 0.262 0.251 0.173 0.117 0.187 0.300
  7      0.640 0.539 0.545 0.574 0.480 0.427 0.337 0.374 0.461
  8      0.705 0.844 0.805 0.796 0.788 0.673 0.630 0.654 0.679
  9      0.781 0.919 0.971 0.942 0.935 0.909 0.835 0.865 0.876
 10      1.000 0.966 0.987 0.994 0.987 0.981 0.969 0.956 0.965
 11      1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
 12+     1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000

Proportion mature at age
Year      1992  1993  1994  1995  1996  1997  1998  1999  2000   1998-2000
Age
  3      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000      0.0000
  4      0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000      0.0000
  5      0.147 0.088 0.091 0.058 0.047 0.061 0.072 0.065 0.058      0.0650
  6      0.362 0.300 0.246 0.251 0.188 0.185 0.235 0.221 0.209      0.2217
  7      0.582 0.565 0.495 0.465 0.483 0.448 0.469 0.482 0.453      0.4680
  8      0.734 0.769 0.758 0.702 0.699 0.747 0.758 0.740 0.733      0.7437
  9      0.880 0.876 0.898 0.901 0.861 0.890 0.925 0.925 0.911      0.9203
 10      0.965 0.954 0.928 0.953 0.960 0.956 0.975 0.982 0.983      0.9800
 11      1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000      1.0000
 12+     1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000      1.0000
```

Table 4.10

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
fleets  danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod
        nortrawlD.cod rustrawltotalD.cod

Model catch in numbers (thousands) at age
Year         1983    1985    1986    1987    1988    1989    1990    1991
Age
  1             0       0       0       0       0       0       0       0
  2             0       0       0       0       0       0       0       0
  3          7089   21580   35922    9556    7558    5572    7112   22361
  4         18019   47442   66674   93940   20105   15780    8154   14227
  5         23133   31120   77647   80451  102862   22908   11329   10177
  6         18280   20121   34319   58645   48499   65424   11137   11126
  7         19867   11522   14295   19710   25591   20443   22313    9753
  8         20583    4005    6302    6347    7361    8540    5090   17514
  9          2792    2424    1944    2514    2120    2164    1725    3663
 10           497    2346    1177     763     814     570     398    1191
 11           220     323    1194     476     245     212     100     266
 12+           86      97     235     605     354     159      69     114
Total      110566  140980  239708  273005  215509  141771   67427   90391

Model catch in numbers (thousands) at age
Year         1992    1993    1994    1995    1996    1997    1998    1999
Age
  1             0       0       0       0       0       0       0       0
  2             0       0       0       0       0       0       0       0
  3         31435   24457   13327    9631    5726   16735   31567   10450
  4         32806   51293   82091   46539   30912   27940   69217   78213
  5         15088   41422   84879  135763   71109   51208   38781   62462
  6          8783   16344   54186   89563  109461   63017   37067   20675
  7          8702    8511   18347   48828   50584   64947   32081   14668
  8          7185    7988    8335   14878   23184   23789   25766   10734
  9         12154    6413    7338    6138    6322    9785    8380    7829
 10          2449   10648    5939    5328    2430    2550    3347    2495
 11           772    2083    9154    4039    2028     942     860     987
 12+          249     886    2625    8159    4871    2809    1386     692
Total      119622  170045  286221  368865  306626  263720  248451  209206
```

Table 4.11

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
fleets  danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod
        nortrawlD.cod rustrawltotalD.cod

Observed catch in numbers (thousands) at age
Year        1983    1985    1986    1987    1988    1989    1990    1991
Age
  1          382      92      33      14       3       2       5      16
  2          475    1504     816     310     171     232     111     369
  3         5275   19827   24601   10451    9320    4905    1318    3498
  4        14129   41156   59095  117702   19556   15829    5815    8518
  5        18164   24947   71522   84258  117466   28910    9871   12313
  6        14398   16756   23485   57247   48956   66518   13789   15180
  7        12598   10562   10443   13079   19909   24998   23675   14196
  8        13092    3509    3796    3576    3153    5194    5160   18101
  9         2148    1437     890     872    1163     795     607    2706
 10          580     713     696     450     384     275     127     270
 11          227     132     517     184     105      41      49      36
 12+          91      97     206     308     128      40      20      14
Total      81559  120732  196100  288451  220314  147739   60547   75217

Observed catch in numbers (thousands) at age
Year        1992    1993    1994    1995    1996    1997    1998    1999
Age
  1           91       9      22       8     175      78      92      21
  2          771     306     167     208     728     664    1453     296
  3        14281    7684    5560    4744    7029   10454   28163    8086
  4        22808   37104   49637   35103   25578   32825   78276   72596
  5        18690   54335   79313   95626   70977   63737   42661   81445
  6        17119   28253   50250   79442   87255   75833   35607   27626
  7        12909   11530   28783   28300   46093   60404   29470   13875
  8         9545    7452    7686    6796    8735   22662   23807   14380
  9        12829    5190    4522    2499    1797    3198    6147    7971
 10         1766    9814    2497    1441     817     817     886    1815
 11          194    1302    5466     811     362     355     172     203
 12+          49     299     853    1871     844     413     136      91
Total     111052  163278  234756  256849  250390  271440  246870  228405
```

Table 4.12

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
fleets  danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod
        nortrawlD.cod rustrawltotalD.cod

Model catch in biomass (t) at age
Year         1983    1985    1986    1987    1988    1989    1990    1991
Age
  1             0       0       0       0       0       0       0       0
  2             0       0       0       0       0       0       0       0
  3          4857   18275   22648    4907    4782    4621    8294   26743
  4         22928   66428   78556   86499   19001   18274   12825   24783
  5         43170   61817  139442  119826  139322   33902   23585   24287
  6         55117   60076   84041  129586   97576  131264   28675   34524
  7         89980   46249   51262   59374   74089   58845   75336   36739
  8        130428   22189   30204   28645   28546   34270   23558   84343
  9         25096   19364   12568   15584   12089   11262   10622   23067
 10          5335   23086   10381    6488    6264    4066    3029    9192
 11          2761    3872   11759    5634    2493    1845     961    2317
 12+         1242    1362    2560    8754    4837    1796     802    1128
Total      380912  322719  443420  465294  388998  300143  187687  267121

Model catch in biomass (t) at age
Year         1992    1993    1994    1995    1996    1997    1998    1999
Age
  1             0       0       0       0       0       0       0       0
  2             0       0       0       0       0       0       0       0
  3         34602   18530    8449    6374    3613   11287   22580    5911
  4         51030   72401   91498   48108   33480   32341   80841   82460
  5         33601   79435  153333  215804  108304   87518   66272  100465
  6         27340   43458  130450  224529  252533  151322   93005   49000
  7         34928   31528   59776  161971  176555  229379  114370   51622
  8         34640   37856   37919   64833  105612  120884  134519   53399
  9         73640   36264   42525   36640   37092   63583   61479   54993
 10         18924   75020   40533   39468   19066   20518   30474   22485
 11          7103   18841   78257   35194   18979    9516    9208   10084
 12+         2453    9937   28951   88024   55212   31352   16218    8118
Total      318258  423270  671690  920945  810447  757700  628964  438537
```

Table 4.13

```
runid BUN28680 Wed Jan 17 09:27:23 2001
stocks cod.imm cod.mat
areas 0
fleets  danish_seineD.cod gillnetD.cod handlineD.cod longlineD.cod
        nortrawlD.cod rustrawltotalD.cod

Observed catch in biomass (t) at age
Year        1983    1985    1986    1987    1988    1989    1990    1991
Age
  1            8      11       3       1       0       0       1       2
  2          214     498     250      75      54     118      49     178
  3         4457   18541   15729    5303    5068    3654    1094    3663
  4        19398   56430   74809  103615   16787   15245    7117   12312
  5        37870   50216  134094  130619  154429   38035   16335   26586
  6        41142   53841   65500  132881  109296  127317   30725   43831
  7        50245   48881   46853   44903   70054   73174   76473   53104
  8        72992   21189   22168   21173   16824   24028   24108   85331
  9        16675   10999    6080    7493    9352    5968    4431   16431
 10         5395    6991    5346    4320    3565    2507    1249    2377
 11         2621    1557    5071    2245    1203     454     649     425
 12+        1498    1366    2301    4193    1974     598     284     232
Total     252514  270521  378203  456821  388606  291097  162514  244473

Observed catch in biomass (t) at age
Year        1992    1993    1994    1995    1996    1997    1998    1999
Age
  1            5       1       1       1      14       8      11       1
  2          420     151      68      83     229     219     508      99
  3        16698    6169    4687    3828    5735    7437   19474    5211
  4        35829   55751   64423   43838   28884   34792   82714   74652
  5        41519  117097  158367  171270  115499   98445   68716  121180
  6        53169   79208  143844  204440  213474  168154   81289   62357
  7        54966   47910   92517  106962  176528  205811   96598   44146
  8        49414   41384   40470   33573   50792  119901  115574   61880
  9        78612   33656   31016   15353   12315   23400   42378   47875
 10        13728   70541   18989   11563    6620    6401    8364   12342
 11         1961   10407   44007    7156    3441    3062    1828    2199
 12+         579    3397    8550   17989    9383    4717    2065    1316
Total     346898  465673  606939  616056  622914  672345  519519  433258
```

Figure 4.1. Initial run; Modelled (full line) and observed (dashed line) survey estimate by length for the Russian bottom trawl survey.

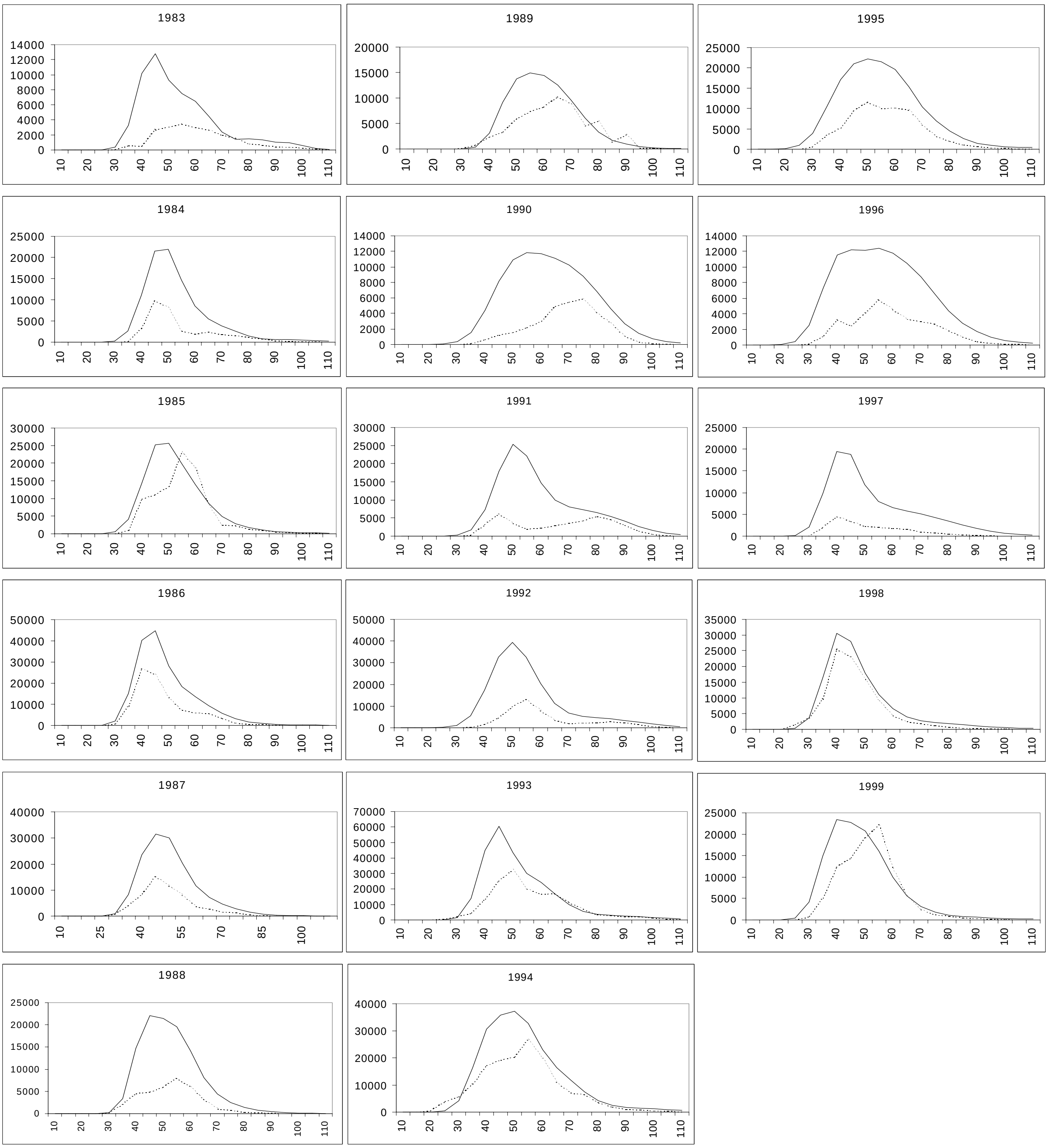


Figure 4.2 Initial run; Modelled (full line) and observed (dashed line) survey estimate by length for the Norwegian bottom trawl winter survey.

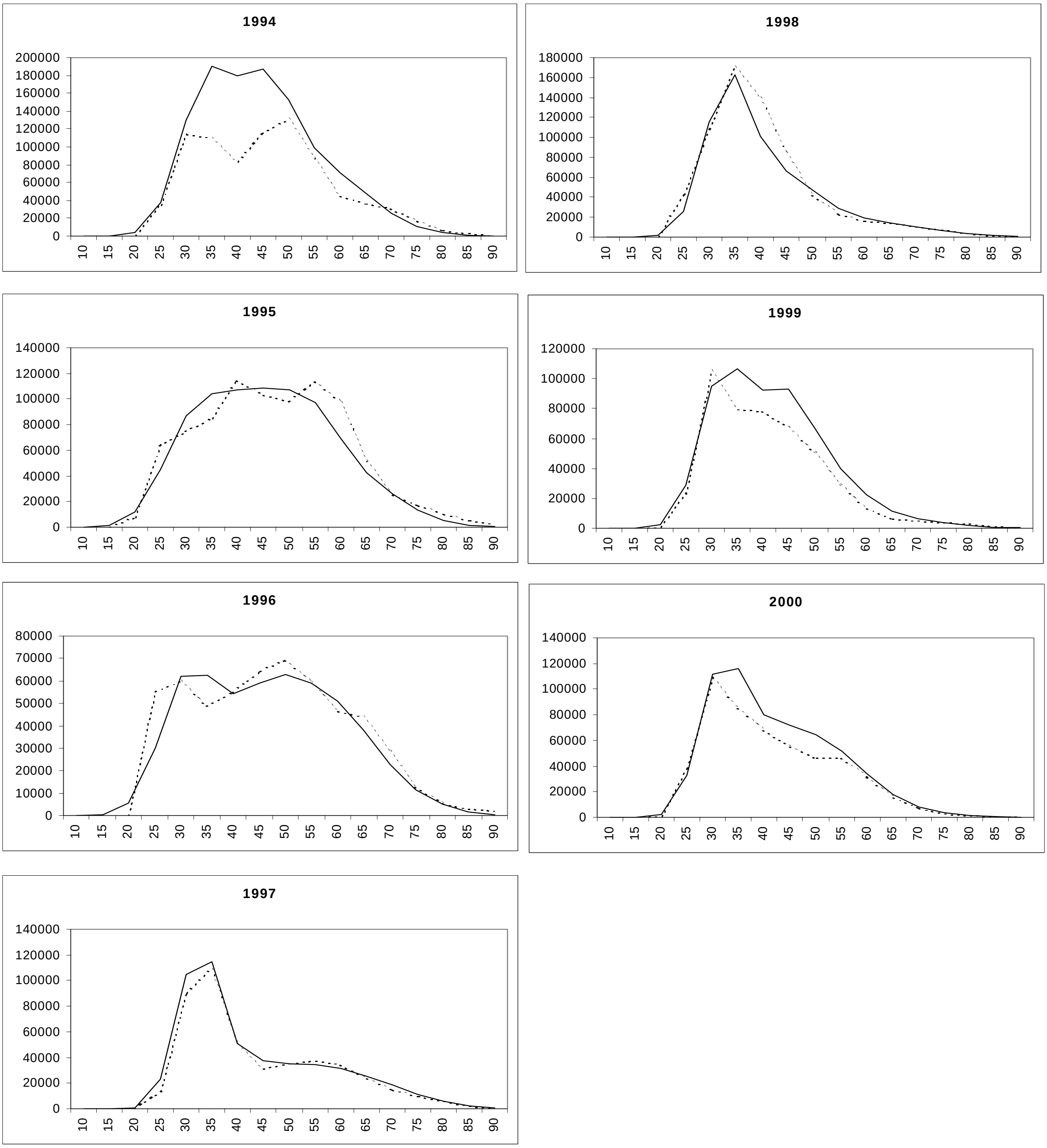


Figure 4.3 Modelled catch when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses) and observed catch (squares).

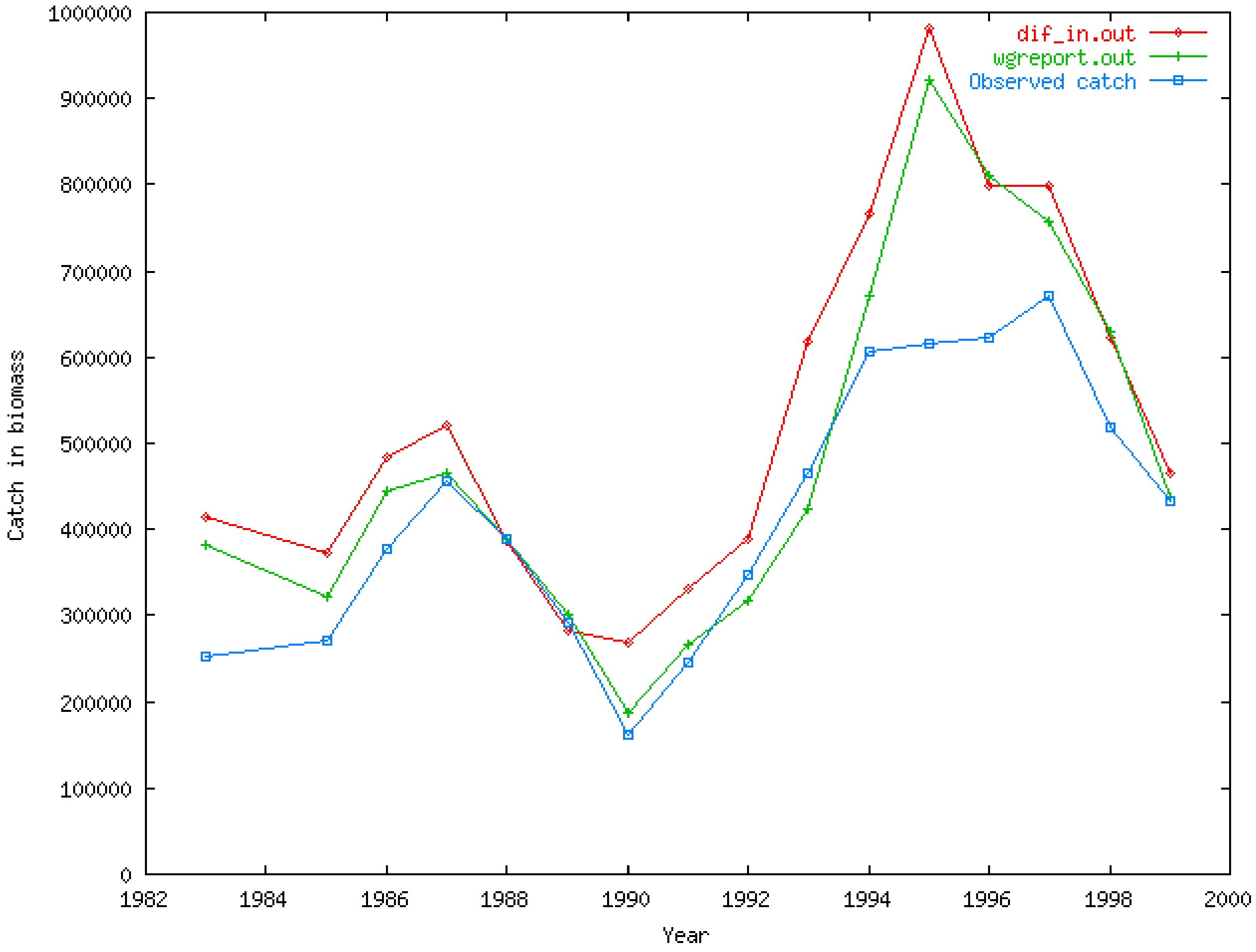


Figure 4.4 Modelled average fishing mortality for ages 5-10 when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses).

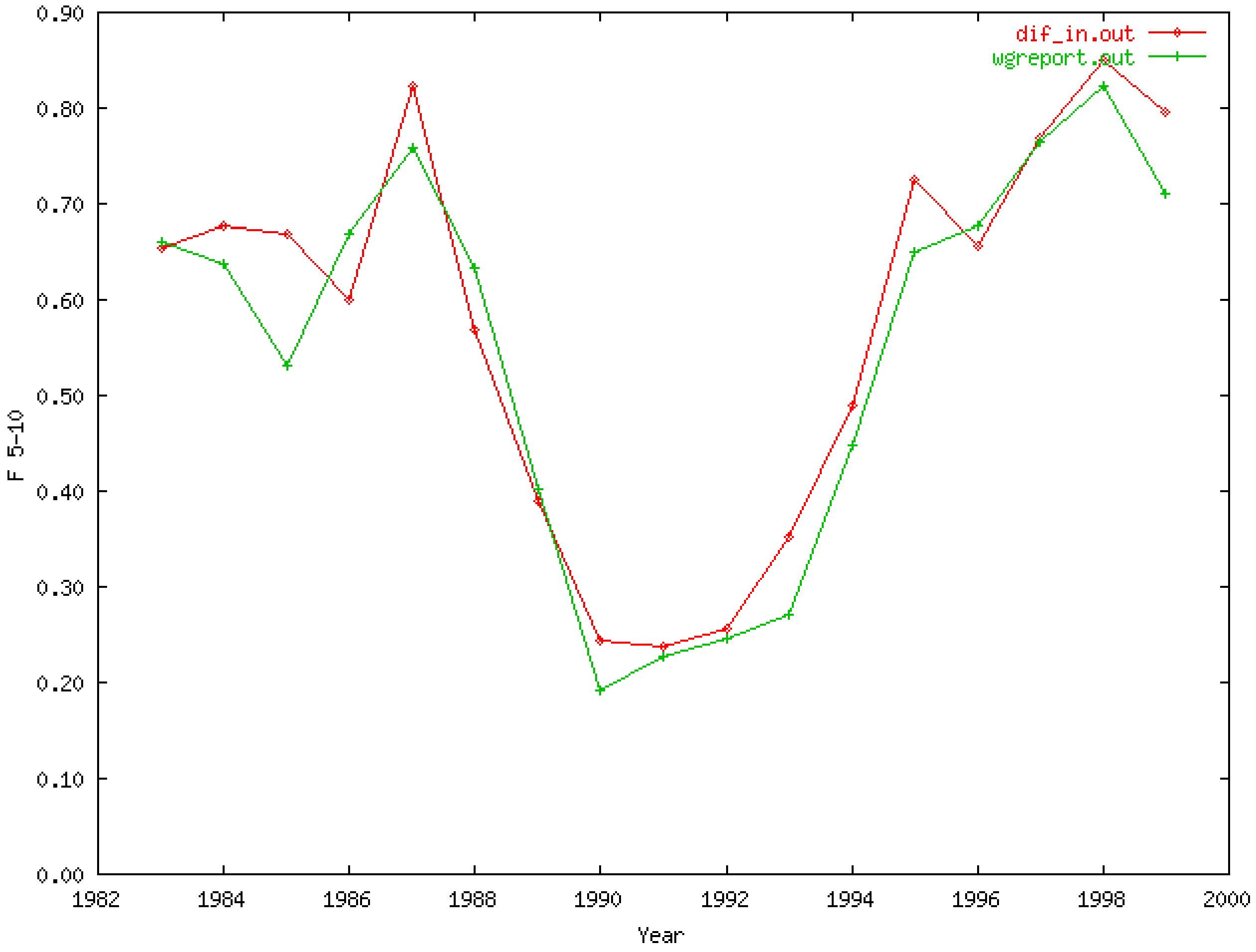


Figure 4.5 Modelled recruitment when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses)

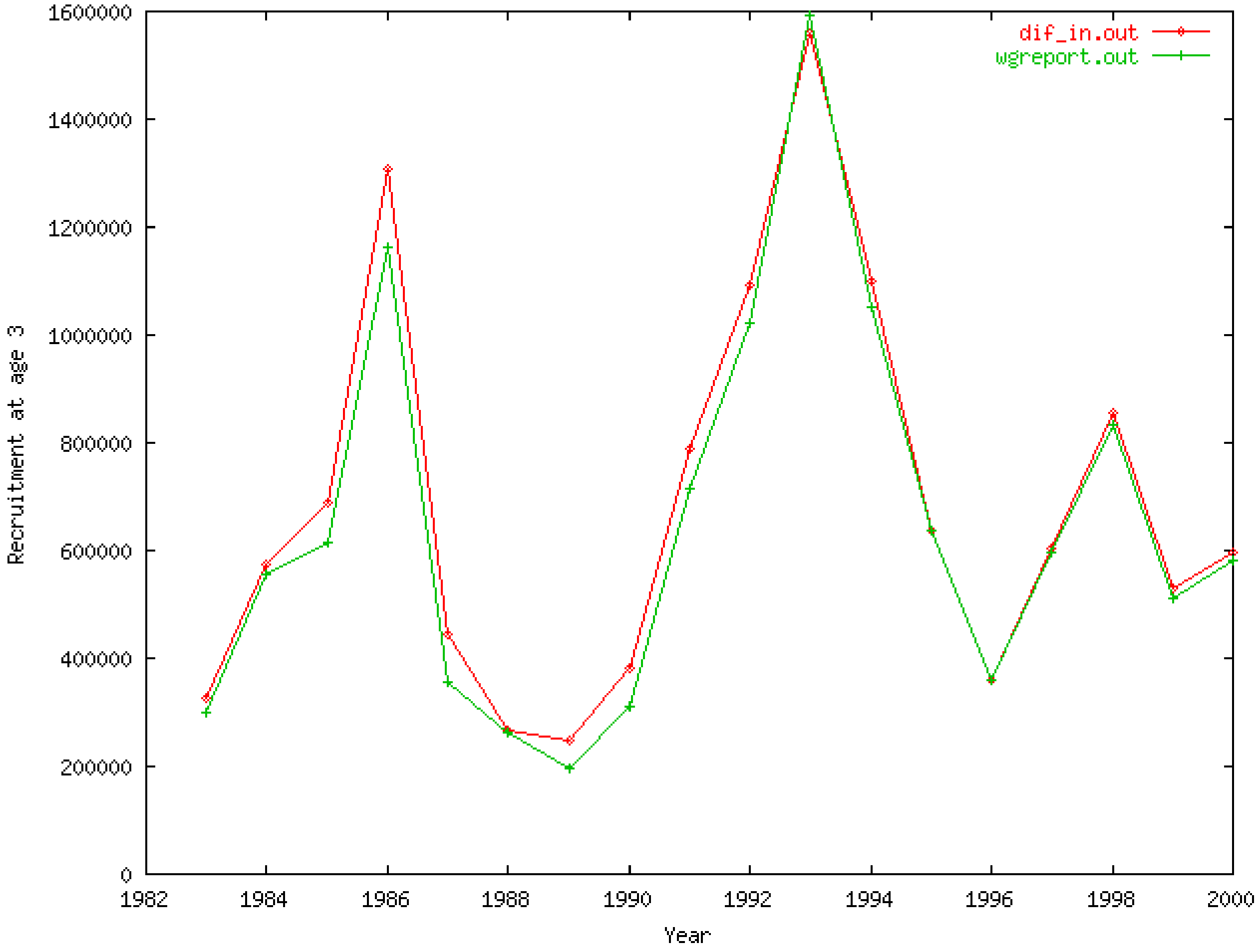
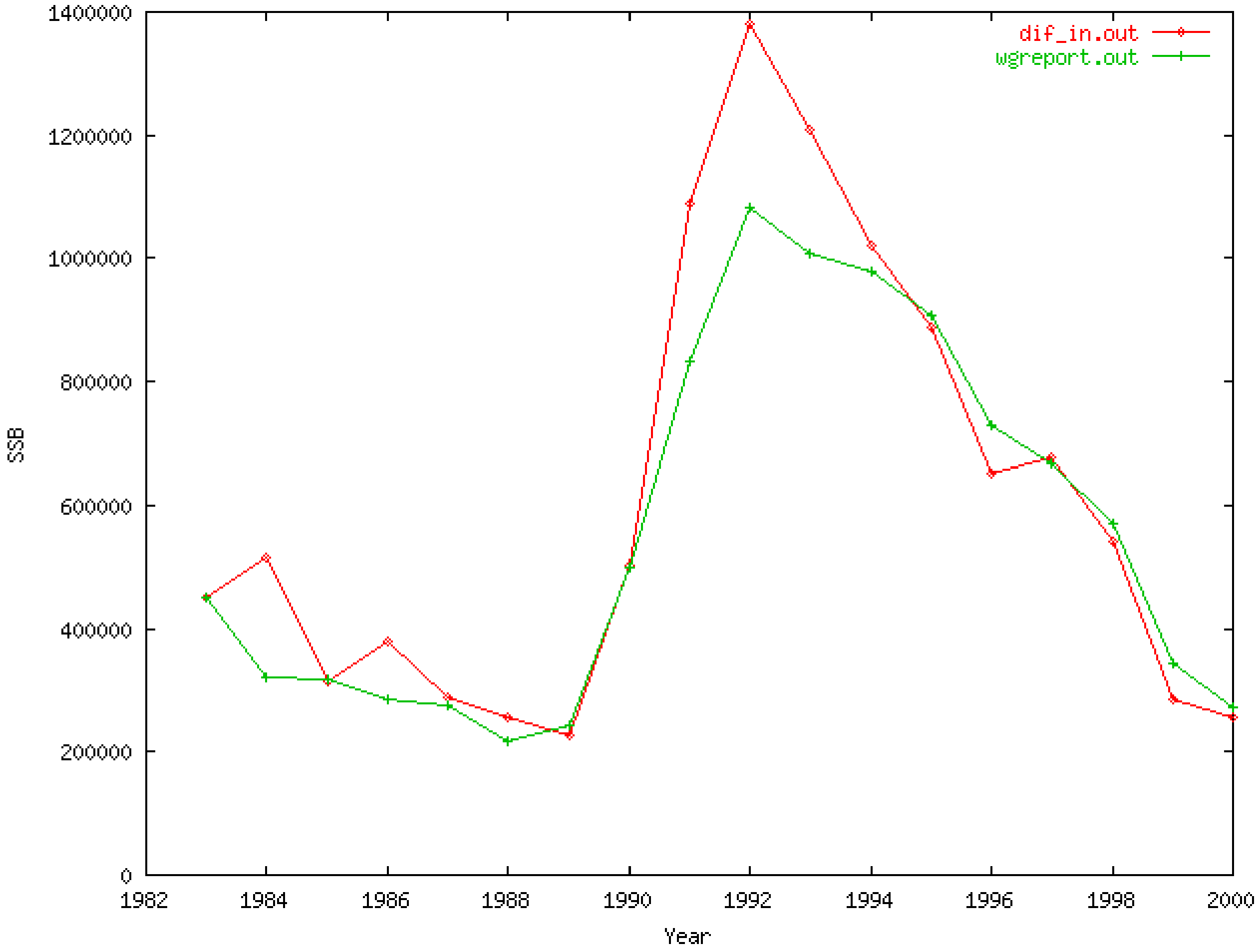


Figure 4.6. Modelled spawning stock biomass when starting values were changed for 15 parameters (diamonds) compared to initial run (pluses).



.

Figure 4.7 Modelled catch when yearly growth rates were fixed (diamonds) compared to initial run (pluses) and observed catch (squares).

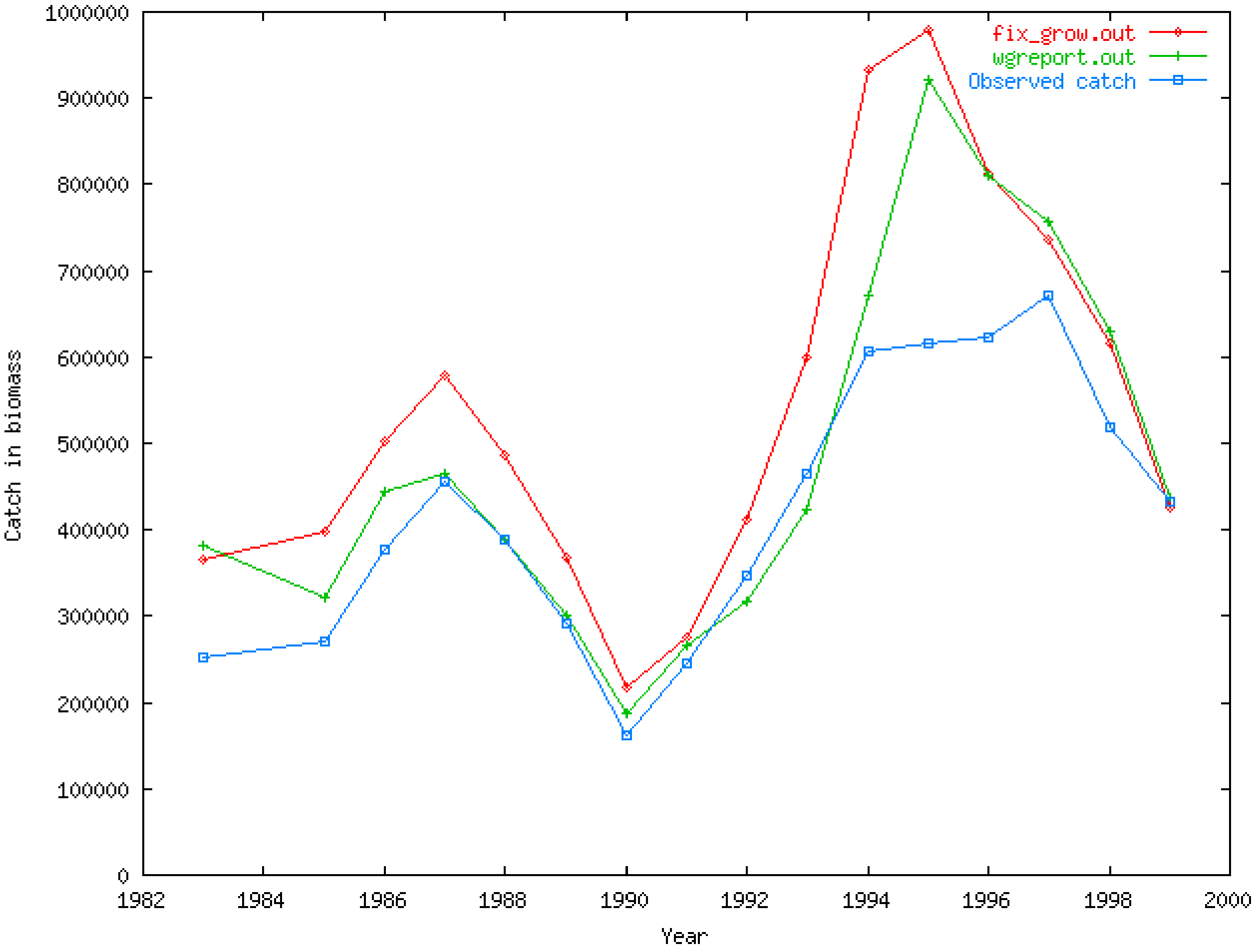


Figure 4.8 Modelled average fishing mortality for ages 5-10 when yearly growth rates were fixed (diamonds) compared to initial run (pluses).

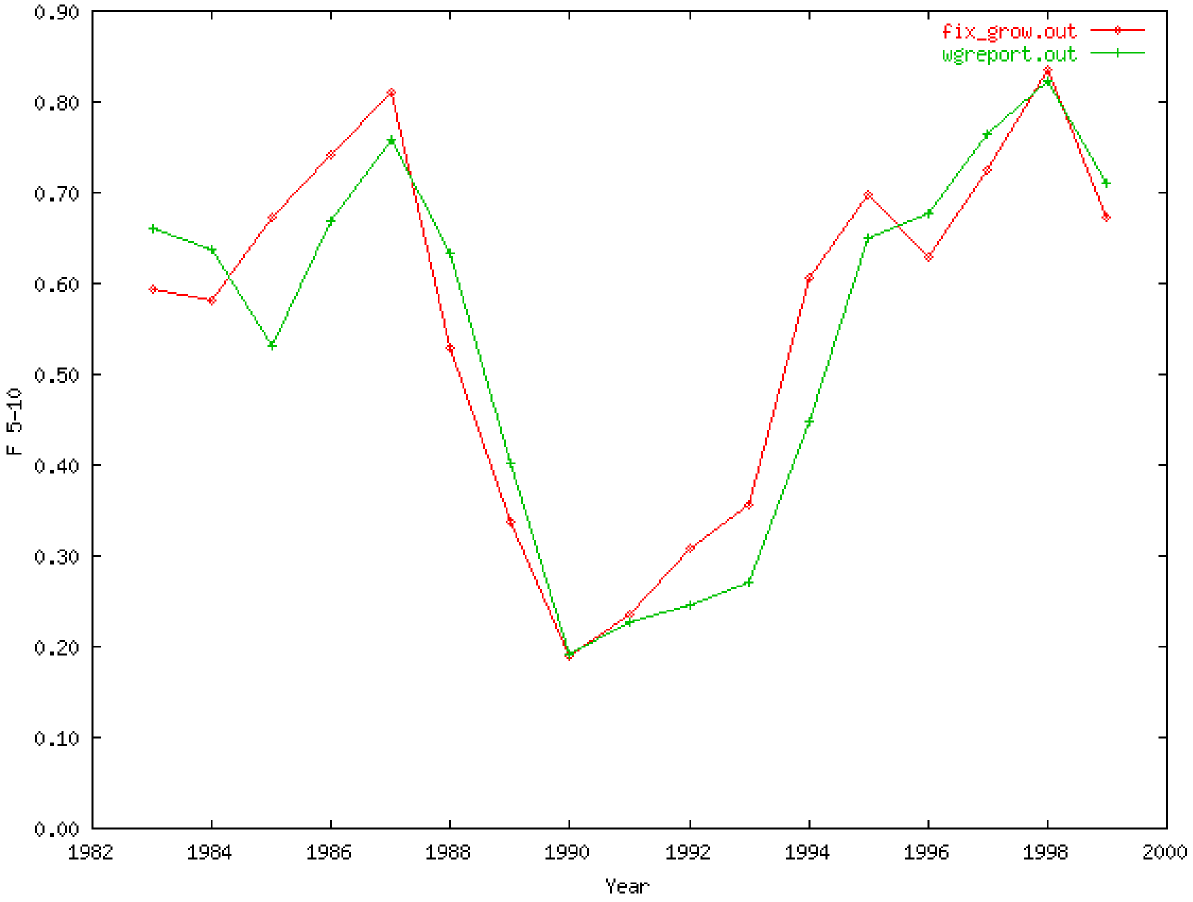


Figure 4.9 Modelled recruitment when yearly growth rates were fixed (diamonds) compared to initial run (pluses).

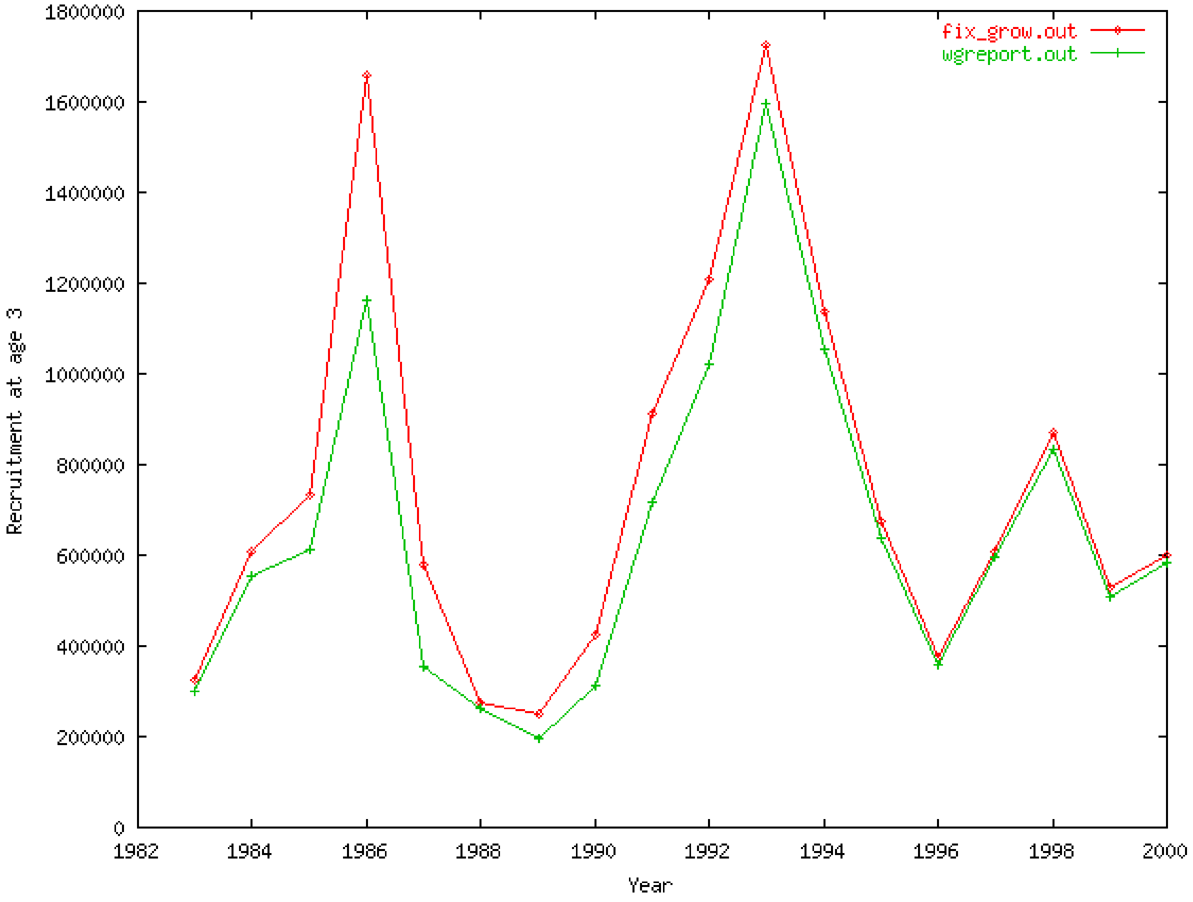


Figure 4.10 Modelled spawning stock biomass when yearly growth rates were fixed (diamonds) compared to initial run (pluses).

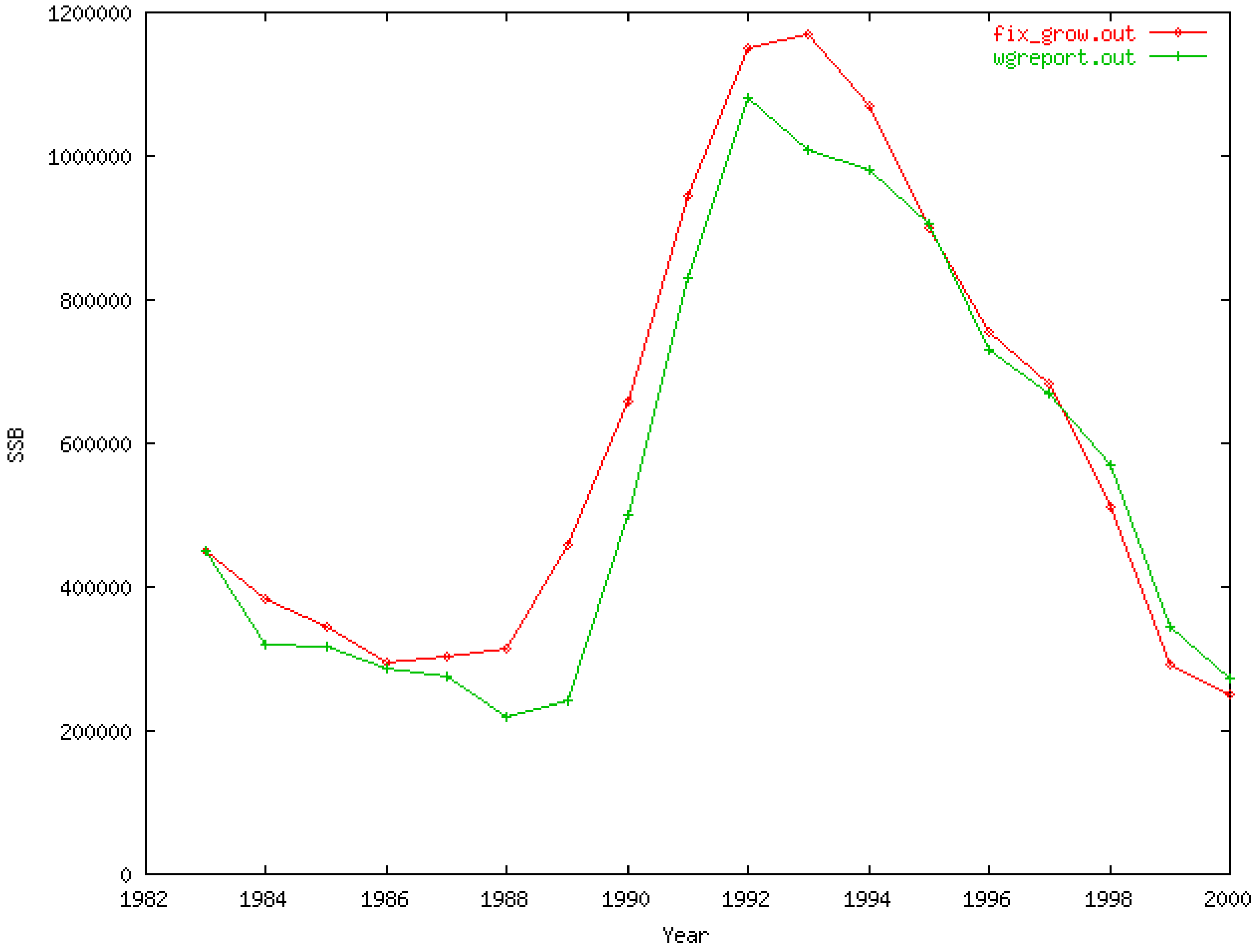


Figure 4.11 Modelled spawning stock biomass when optimising alpha in the consumption equation (pluses) compared to initial run (diamonds) and the assessment at AFWG, August 2000 (squares).

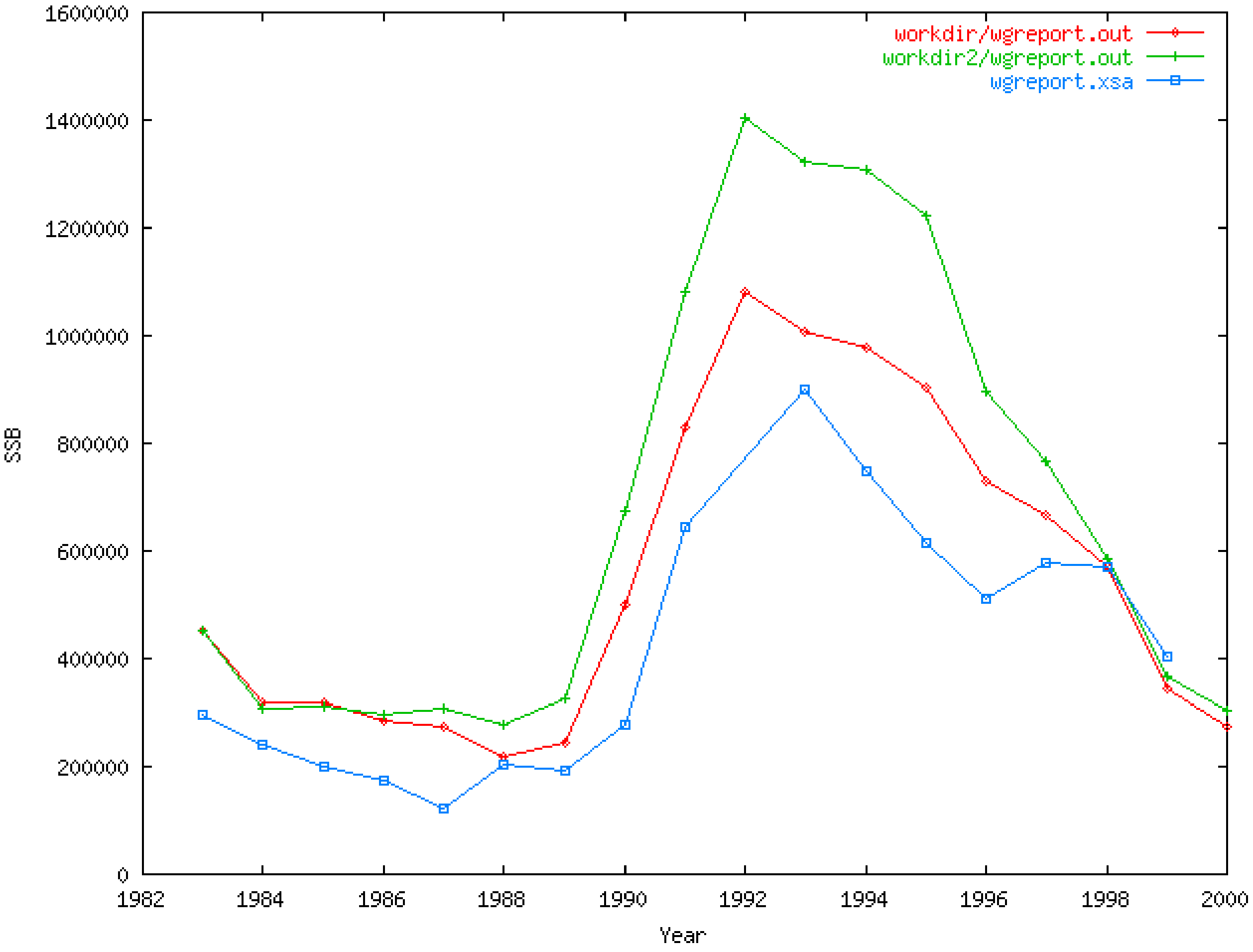


Figure 4.12 Modelled catch when optimising alpha in the consumption equation (pluses) compared to initial run (diamonds) and the observed catch (x-es).

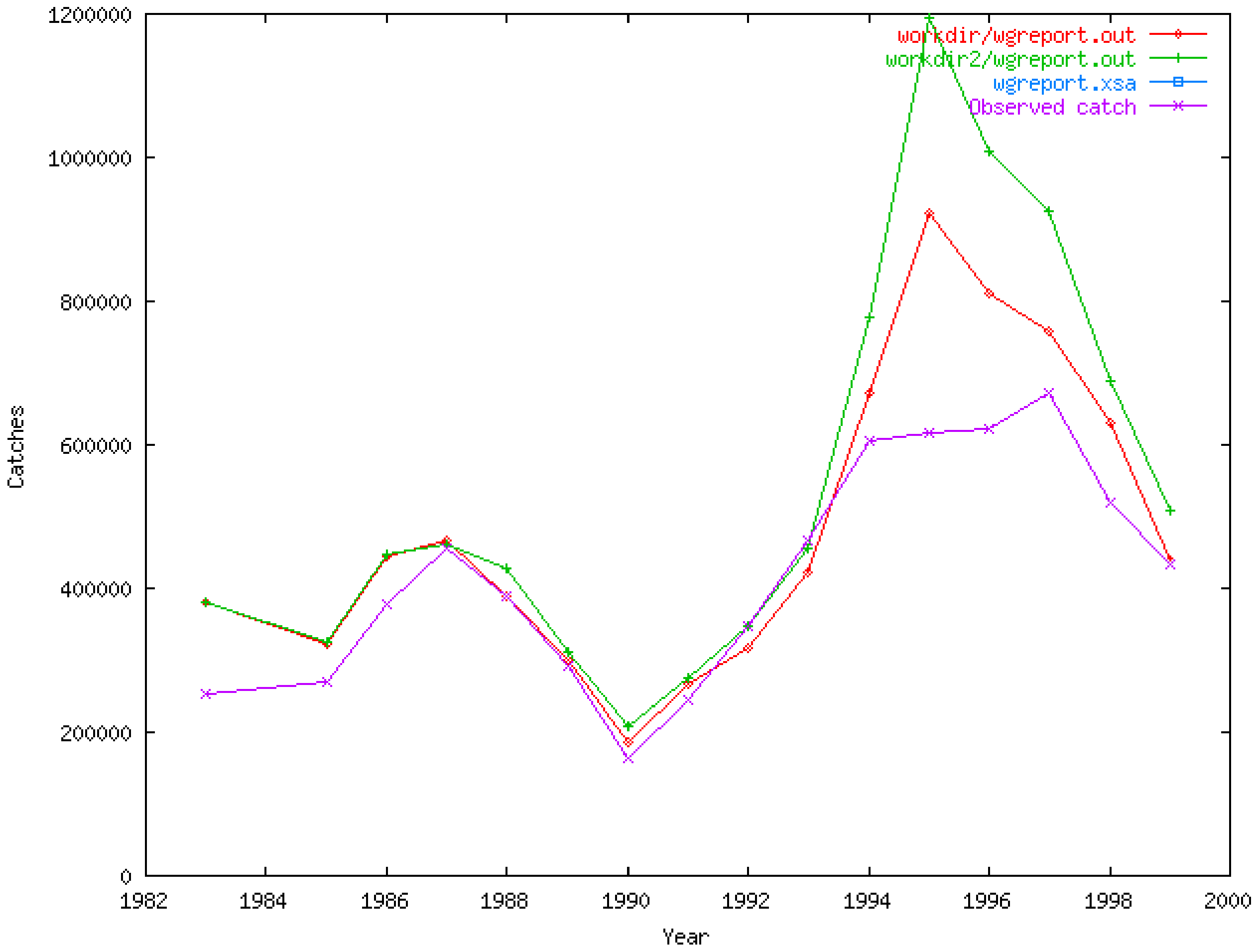
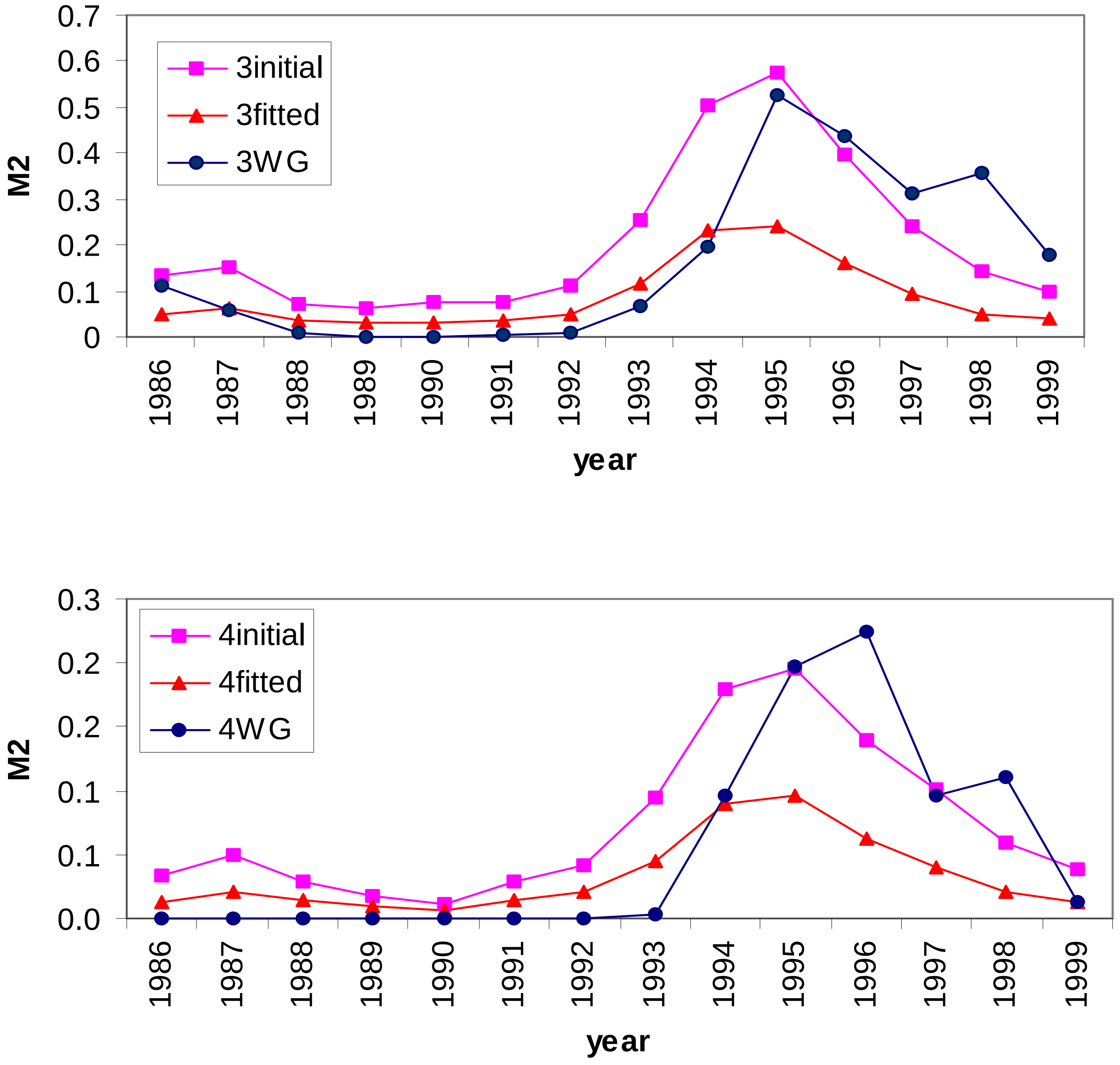


Figure 4.13 Estimated predation mortality (M2) for age 3 (upper panel) and age 4 (lower panel) in the initial run ("initial") and in the run where alpha in the consumption equation was optimised ("fitted") and in the assessment at AFWG, August 2000 ("WG").



APPENDIX 1

```
;This optfile was generated from runid BUN28680 Tue Jan 16 16:51:45 2001
switches                   value                   optimize

;Growth parameter for each year
growth.1983      7.500481    1 ;[12.4448   ]
growth.1984      12.7195     1 ;[12.7195   ]
growth.1985      8.36056     1 ;[8.36056   ]
growth.1986      8.41845     1 ;[8.41845   ]
growth.1987      5.659269    1 ;[5.14479   ]
growth.1988      8.21156     1 ;[8.21156   ]
growth.1989      13.50927    1 ;[15.0103   ]
growth.1990      10.107798   1 ;[9.44654   ]
growth.1991      8.956818    1 ;[9.95202   ]
growth.1992      4.424553    1 ;[4.91617   ]
growth.1993      7.859772    1 ;[8.73308   ]
growth.1994      8.05806     1 ;[8.9534    ]
growth.1995      8.579318    1 ;[7.79938   ]
growth.1996      10.9841     1 ;[10.9841   ]
growth.1997      12.482176   1 ;[11.1448   ]
growth.1998      10.457571   1 ;[11.2447   ]
growth.1999      10.187144   1 ;[11.5763   ]
growth.2000      9.6         1 ;[9.6       ]

;Growth distribution parameters
growth.k0        -0.072783   0 ;             Growth distribution param. k0
growth.k1        0.5947425   1 ;[0.540675  ] Growth distribution param. k1
growth.exponent  0           0
growth.ratio     0.88        1 ;[0.8       ] Ratio of Mature/immature growth
;Cannibalism parameters
cann_beta        0.00103295  0 ;             Cannibalism parameter beta
cann_gamma       0.0001      0 ;             Cannibalism parameter gamma
cann_delta       0.309428    0 ;             Cannibalism parameter delta
cann_alpha       7e-06       0 ;             Cannibalism parameter alpha
;Quarterly natural residual mortality of immature fish (in 3 length intervals)
imm.mort1        0.05        0 ;             Quart. imm mortality length 1
imm.mort2        0.05        0 ;             Quart. imm mortality length 2
imm.mort3        0.05        0 ;             Quart. imm mortality length 3
;Number of immature fish in startyear of age x (10^7)
imm.n_age3       30.125851   1 ;[24.3579   ]
imm.n_age4       14.997377   1 ;[13.8161   ]
imm.n_age5       9.6564423   1 ;[6.61219   ]
imm.n_age6       3.6446964   1 ;[4.53659   ]
imm.n_age7       1.7841371   1 ;[2.80878   ]
imm.n_age8       1.6088661   1 ;[2.62073   ]
imm.n_age9       0.1727837   1 ;[0.364292  ]
imm.n_age10      0           0
;Mean length (cm) of immature fish in startyear at age x
imm.l_age3       34.8        0
imm.l_age4       45.9        0
imm.l_age5       54.5        0
imm.l_age6       62.7        0
imm.l_age7       73.1        0
imm.l_age8       78.6        0
imm.l_age9       85          0
imm.l_age10      90          0
```

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```
;Standard Deviation of mean length of immature fish in startyear at age x
imm.d_age3       4.2         0
imm.d_age4       4.7         0
imm.d_age5       4.3         0
imm.d_age6       5.2         0
imm.d_age7       4.2         0
imm.d_age8       6.8         0
imm.d_age9       13.7        0
imm.d_age10      13.5        0

;Maturation parameters
maturation.slope 0.03        0 ;             Maturation, slope
maturation.l50   78.44       0 ;             Maturation, L50
;Number of minimum-age fish at start of year x (10^7)
n_minage.1984    55.429371   1 ;[53.4259   ]
n_minage.1985    61.420098   1 ;[60.818    ]
n_minage.1986    116.44502   1 ;[123.105   ]
n_minage.1987    35.517037   1 ;[46.4093   ]
n_minage.1988    26.2487     1 ;[35.5      ]
n_minage.1989    19.527306   1 ;[22.4426   ]
n_minage.1990    31.26683    1 ;[37.6845   ]
n_minage.1991    71.476955   1 ;[54.2067   ]
n_minage.1992    102.05567   1 ;[89.8773   ]
n_minage.1993    159.40982   1 ;[115.867   ]
n_minage.1994    105.36738   1 ;[106.185   ]
n_minage.1995    63.747093   1 ;[61.5676   ]
n_minage.1996    35.9254     1 ;[41.7543   ]
n_minage.1997    59.449775   1 ;[69.3211   ]
n_minage.1998    83.341917   1 ;[84.7229   ]
n_minage.1999    51.036035   1 ;[48.2519   ]
n_minage.2000    58.137946   1 ;[57.9294   ]

;Mean length of minimum-age fish at start of year x
l_minage.1984    34.4754     1 ;[35.8      ]
l_minage.1985    37.1566     1 ;[40.3      ]
l_minage.1986    33.88056    1 ;[34.4      ]
l_minage.1987    33.43134    1 ;[31.8      ]
l_minage.1988    33.73326    1 ;[29.7      ]
l_minage.1989    34.4224     1 ;[34.7      ]
l_minage.1990    38.46228    1 ;[39.4      ]
l_minage.1991    40.7264     1 ;[41.6      ]
l_minage.1992    41.88646    1 ;[41.3      ]
l_minage.1993    34.9307     1 ;[35.9      ]
l_minage.1994    31.293      1 ;[30.5      ]
l_minage.1995    29.02692    1 ;[29.9      ]
l_minage.1996    28.31356    1 ;[28.1      ]
l_minage.1997    29.9292     1 ;[28        ]
l_minage.1998    31.09358    1 ;[28.7      ]
l_minage.1999    29.348      1 ;[29        ]
l_minage.2000    29.23382    1 ;[28.7      ]
```

Continued……

```
;Standard deviation of mean length of minimum-age fish at start of year x
d_minage.1984    4.3         0
d_minage.1985    5.1         0
d_minage.1986    4.4         0
d_minage.1987    3.5         0
d_minage.1988    3.1         0
d_minage.1989    3.4         0
d_minage.1990    6.8         0
d_minage.1991    5.8         0
d_minage.1992    6.5         0
d_minage.1993    4.4         0
d_minage.1994    5           0
d_minage.1995    5.9         0
d_minage.1996    5           0
d_minage.1997    3.9         0
d_minage.1998    4.4         0
d_minage.1999    4.2         0
d_minage.2000    4.1         0

;Quarterly natural residual mortality of mature fish (in 3 length intervals)
mat.mort1        0.05        0 ;             Quart. mat mortality length 1
mat.mort2        0.05        0 ;             Quart. mat mortality length 2
mat.mort3        0.05        0 ;             Quart. mat mortality length 3

;Number of mature fish in startyear of age x (10^7)
mat.n_age4       0.94        0
mat.n_age5       0.81        0
mat.n_age6       1.49        0
mat.n_age7       2.53        0
mat.n_age8       2.77        0
mat.n_age9       0.44        0
mat.n_age10      0.11        0
mat.n_age11      0.05        0
mat.n_age12      0.02        0

;Mean length (cm) of mature fish in startyear at age x
mat.l_age4       51          0
mat.l_age5       59.6        0
mat.l_age6       71.1        0
mat.l_age7       79          0
mat.l_age8       88.2        0
mat.l_age9       97.3        0
mat.l_age10      100         0
mat.l_age11      105         0
mat.l_age12      110         0

;Standard Deviation of mean length of mature fish in startyear at age x
mat.d_age4       1.06835     0
mat.d_age5       1.05602     0
mat.d_age6       1.01149     0
mat.d_age7       1.82767     0
mat.d_age8       2.56627     0
mat.d_age9       4.00303     0
mat.d_age10      7.15294     0
mat.d_age11      7.33135     0
mat.d_age12      9.03202     0
```

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```
;fleet names
;11 dan  - Danish seine
;12 gil  - Gillnet
;13 hnd  - Handline
;14 lng  - Longline
;15 nor  - Norwegian trawl
;16 rus  - Russian trawl
;17 trd  - Third countries
;18 ovr  - Overfishing
;Catches, selection parameters
;05 slope
;06 l50

;Danish seine
dan.slope        0.067852885  1 ;[0.0607076 ] Slope of selection curve
dan.l50          45.961647   1 ;[48.9944   ] L50 of selection curve
dan.f1983        0.054864692  1 ;[0.0587794 ] Partial F
dan.f1985        0.023539584  1 ;[0.0219238 ]
dan.f1986        0.023756406  1 ;[0.0221278 ]
dan.f1987        0.0087118268  1 ;[0.0104634 ]
dan.f1988        0.013480782  1 ;[0.0181976 ]
dan.f1989        0.013860523  1 ;[0.0176029 ]
dan.f1990        0.0063175232  1 ;[0.00826144]
dan.f1991        0.0058644727  1 ;[0.00635922]
dan.f1992        0.0044601598  1 ;[0.00595641]
dan.f1993        0.007392659  1 ;[0.0086952 ]
dan.f1994        0.010762389  1 ;[0.0133794 ]
dan.f1995        0.024649586  1 ;[0.0230026 ]
dan.f1996        0.060172148  1 ;[0.0550674 ]
dan.f1997        0.037391022  1 ;[0.0704295 ]
dan.f1998        0.049328359  1 ;[0.0732092 ]
dan.f1999        0.039700965  1 ;[0.0466631 ]

;Gillnet
gil.p0           0           0 ; Parameters for bell-shaped selection curve
gil.p1           0.20138     1 ;[0.2       ]
gil.p2           1           0
gil.p3           0.052317    1 ;[0.03      ]
gil.p4           0.18603     1 ;[0.1       ]
gil.f1983        0.2916      1 ;[0.5       ] Partial F
gil.f1985        0.25587     1 ;[0.45      ]
gil.f1986        0.17688     1 ;[0.3       ]
gil.f1987        0.11294     1 ;[0.2       ]
gil.f1988        0.15171     1 ;[0.3       ]
gil.f1989        0.13908     1 ;[0.3       ]
gil.f1990        0.028421045  1 ;[0.0946737 ]
gil.f1991        0.0326      1 ;[0.1       ]
gil.f1992        0.037814    1 ;[0.074     ]
gil.f1993        0.055104    1 ;[0.12      ]
gil.f1994        0.077779    1 ;[0.13      ]
gil.f1995        0.19629     1 ;[0.27      ]
gil.f1996        0.17421     1 ;[0.3       ]
gil.f1997        0.19311     1 ;[0.3       ]
gil.f1998        0.13992     1 ;[0.2       ]
gil.f1999        0.14368     1 ;[0.2       ]
```

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```
;Handline
hnd.slope        0.038828744  1 ;[0.0405734 ] Slope of selection curve
hnd.l50          59.466      1 ;[53        ] L50 of selection curve
hnd.f1983        0.075431748  1 ;[0.0756208 ] Partial F
hnd.f1985        0.10155915  1 ;[0.0800624 ]
hnd.f1986        0.084480353  1 ;[0.0642485 ]
hnd.f1987        0.015452647  1 ;[0.0177128 ]
hnd.f1988        0.011670499  1 ;[0.0122281 ]
hnd.f1989        0.021178084  1 ;[0.0238063 ]
hnd.f1990        0.016107895  1 ;[0.0146502 ]
hnd.f1991        0.014208944  1 ;[0.0149757 ]
hnd.f1992        0.014069016  1 ;[0.015031  ]
hnd.f1993        0.019265681  1 ;[0.0211967 ]
hnd.f1994        0.025607546  1 ;[0.0236036 ]
hnd.f1995        0.019794781  1 ;[0.0138551 ]
hnd.f1996        0.018006997  1 ;[0.0140966 ]
hnd.f1997        0.023647875  1 ;[0.0230576 ]
hnd.f1998        0.027326092  1 ;[0.0360075 ]
hnd.f1999        0.048321997  1 ;[0.0518532 ]

;Longline
lng.slope        0.042876211  1 ;[0.0403351 ] Slope of selection curve
lng.l50          60          1 ;[53        ] L50 of selection curve
lng.f1983        0.12865     1 ;[0.1       ] Partial F
lng.f1985        0.066131775  1 ;[0.0603888 ]
lng.f1986        0.10555025  1 ;[0.118796  ]
lng.f1987        0.123474    1 ;[0.13      ]
lng.f1988        0.131085    1 ;[0.15      ]
lng.f1989        0.070260789  1 ;[0.0994491 ]
lng.f1990        0.015243247  1 ;[0.0181273 ]
lng.f1991        0.013427487  1 ;[0.0153615 ]
lng.f1992        0.012314316  1 ;[0.0146599 ]
lng.f1993        0.019742464  1 ;[0.0228395 ]
lng.f1994        0.038675033  1 ;[0.0411349 ]
lng.f1995        0.074166473  1 ;[0.062821  ]
lng.f1996        0.080220102  1 ;[0.0752675 ]
lng.f1997        0.075102682  1 ;[0.101545  ]
lng.f1998        0.077044687  1 ;[0.112065  ]
lng.f1999        0.078645937  1 ;[0.109276  ]

;Norwegian trawl
nor.slope        0.044906956  1 ;[0.0395656 ] Slope of selection curve
nor.l50          53.872      1 ;[52        ] L50 of selection curve
nor.f1983        0.14628     1 ;[0.1       ] Partial F
nor.f1985        0.08535     1 ;[0.05      ]
nor.f1986        0.153374    1 ;[0.13      ]
nor.f1987        0.34792971  1 ;[0.425498  ]
nor.f1988        0.226198    1 ;[0.14      ]
nor.f1989        0.09457     1 ;[0.1       ]
nor.f1990        0.035952    1 ;[0.04      ]
nor.f1991        0.021464    1 ;[0.02      ]
nor.f1992        0.027309    1 ;[0.03      ]
nor.f1993        0.04245     1 ;[0.05      ]
nor.f1994        0.099638    1 ;[0.07      ]
nor.f1995        0.130242    1 ;[0.07      ]
nor.f1996        0.127498    1 ;[0.07      ]
nor.f1997        0.133395    1 ;[0.15      ]
nor.f1998        0.142668    1 ;[0.18      ]
nor.f1999        0.12935     1 ;[0.1       ]
```

Continued……

```
;Russian trawl
rus.slope        0.06457127  1 ;[0.0564928 ] Slope of selection curve
rus.l50          47.526612   1 ;[50.1759   ] L50 of selection curve
rus.f1983        0.04302968  1 ;[0.0444292 ] Partial F
rus.f1985        0.081625    1 ;[0.05      ]
rus.f1986        0.18336     1 ;[0.1       ]
rus.f1987        0.18606     1 ;[0.1       ]
rus.f1988        0.208233    1 ;[0.17      ]
rus.f1989        0.145894    1 ;[0.14      ]
rus.f1990        0.055542    1 ;[0.03      ]
rus.f1991        0.079646    1 ;[0.07      ]
rus.f1992        0.08303     1 ;[0.05      ]
rus.f1993        0.111516    1 ;[0.06      ]
rus.f1994        0.16099     1 ;[0.1       ]
rus.f1995        0.239083    1 ;[0.13      ]
rus.f1996        0.260028    1 ;[0.18      ]
rus.f1997        0.36594     1 ;[0.36      ]
rus.f1998        0.42816     1 ;[0.24      ]
rus.f1999        0.332266    1 ;[0.22      ]

;Overfishing
ovr.slope        0.04        0 ;             Slope of selection curve
ovr.l50          52          0 ;             L50 of selection curve
ovr.f1983        0           0 ;             Partial F
ovr.f1985        0           0
ovr.f1986        0           0
ovr.f1987        0           0
ovr.f1988        0           0
ovr.f1989        0           0
ovr.f1990        0.03        0
ovr.f1991        0.07        0
ovr.f1992        0.08        0
ovr.f1993        0.03        0
ovr.f1994        0.015       0
ovr.f1995        0           0
ovr.f1996        0           0
ovr.f1997        0           0
ovr.f1998        0           0
ovr.f1999        0           0

;survey names
;1 lofac   - Lofoten acoustic (1985-2000)
;2 ba1tr   - Barents Sea trawl (1983-1993)
;3 ba1ac   - Barents Sea acoustic (1983-1993)
;4 svatr   - Svalbard bottom trawl survey (1987-1999) not in use at present
;5 ba2ac   - Barents Sea acoustic (1994-2000)
;6 ba2tr   - Barents Sea trawl (1994-2000)
;7 rustr   - Russian autumn bottom trawl survey - 1982-1999
;8 nortr   - Norwegian summer (autumn) survey - bottom trawl (1995-1999)
;Survey catchability parameter names
;04 cbt    - Catchability
;01 b0     - Exponent (for power fit) or constant (for linear fit)
;02 slope  - Slope
;03 l50    - L50

;Barents Sea trawl (1983-1993)
;ba1tr.cbt        0.4           1 ;Catchability
;ba1tr.b0         1             0 ;b0
;ba1tr.slope      0.05          1 ;Slope
;ba1tr.l50        20.0          1 ;L50
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Continued……

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;Barents Sea trawl (1994-2000)
ba2tr.cbt        0.4450967   1 ;[0.45344   ] Catchability
ba2tr.b0         1           0 ;             b0
ba2tr.slope      0.05        0 ;             Slope
ba2tr.l50        5           0 ;             L50

;Lofoten acoustic (1985-2000)
lofac.cbt        0.6353      1 ;[0.5       ] Catchability
lofac.b0         1           0 ;             b0
lofac.slope      0.05        0 ;             Slope
lofac.l50        5           0 ;             L50

;Barents Sea acoustic (1983-1993)
;ba1ac.cbt        0.666635      1 ;Catchability
;ba1ac.b0         1             0 ;b0
;ba1ac.slope      0.05          1 ;Slope
;ba1ac.l50        20.0          1 ;L50

;Barents Sea acoustic (1994-2000)
ba2ac.cbt        0.43007066  1 ;[0.43503   ] Catchability
ba2ac.b0         1           0 ;             b0
ba2ac.slope      0.05        0 ;             Slope
ba2ac.l50        5           0 ;             L50

;Russian autumn bottom trawl survey - 1982-1999
rustr.cbt        0.13388     1 ;[0.2       ] Catchability
rustr.b0         1           0 ;             b0
rustr.slope      0.26339398  1 ;[0.141564  ] Slope
rustr.l50        1           1 ;[1         ] L50

;Norwegian summer (autumn) survey - bottom trawl (1995-1999)
nortr.cbt        0.63386493  1 ;[0.62168   ] Catchability
nortr.b0         1           0 ;             b0
nortr.slope      0.05        0 ;             Slope
nortr.l50        5           0 ;             L50
```

APPENDIX 2

```
switches                   value                  optimize
;Growth parameter for each year
growth.1983      10.0       1 ;12.448
growth.1984      10.0       1 ;12.7195
growth.1985      10.0       1 ;8.36056
growth.1986      10.0       1 ;8.41845
growth.1987      10.0       1 ;5.14479
growth.1988      8.21156       1
growth.1989      15.0103       1
growth.1990      9.44654       1
growth.1991      9.95202       1
growth.1992      4.91617       1
growth.1993      8.73308       1
growth.1994      8.9534        1
growth.1995      7.79938       1
growth.1996      10.9841       1
growth.1997      11.1448       1
growth.1998      11.2447       1
growth.1999      11.5763       1
growth.2000      9.6           1

;Growth distribution parameters
growth.k0        -0.072783     0 ;Growth distribution param. k0
growth.k1        1.0        1 ;Growth distribution param. k1 0.540675
growth.exponent  0             0
growth.ratio     0.8           1 ;Ratio of Mature/immature growth

;Cannibalism parameters
cann_beta        0.00103295    0 ;Cannibalism parameter beta
cann_gamma       0.0001        0 ;Cannibalism parameter gamma
cann_delta       0.309428      0 ;Cannibalism parameter delta
cann_alpha       7e-06         0 ;Cannibalism parameter alpha

;Quarterly natural residual mortality of immature fish (in 3 length intervals)
imm.mort1        0.05          0 ;Quart. imm mortality length 1
imm.mort2        0.05          0 ;Quart. imm mortality length 2
imm.mort3        0.05          0 ;Quart. imm mortality length 3

;Number of immature fish in startyear of age x (10^7)
imm.n_age3       15.0       1 ;24.3579
imm.n_age4       13.8161       1
imm.n_age5       6.61219       1
imm.n_age6       4.53659       1
imm.n_age7       2.80878       1
imm.n_age8       2.62073       1
imm.n_age9       0.364292      1
imm.n_age10      0             0

;Mean length (cm) of immature fish in startyear at age x
imm.l_age3       34.8          0
imm.l_age4       45.9          0
imm.l_age5       54.5          0
imm.l_age6       62.7          0
imm.l_age7       73.1          0
imm.l_age8       78.6          0
imm.l_age9       85            0
imm.l_age10      90            0
```

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```
;Standard Deviation of mean length of immature fish in startyear at age x
imm.d_age3       4.2           0
imm.d_age4       4.7           0
imm.d_age5       4.3           0
imm.d_age6       5.2           0
imm.d_age7       4.2           0
imm.d_age8       6.8           0
imm.d_age9       13.7          0
imm.d_age10      13.5          0

;Maturation parameters
maturation.slope 0.03          0 ;Maturation, slope
maturation.l50   78.44         0 ;Maturation, L50

;Number of minimum-age fish at start of year x (10^7)
n_minage.1984    53.4259       1
n_minage.1985    60.818        1
n_minage.1986    60.105        1 ;123.105
n_minage.1987    46.4093       1
n_minage.1988    35.5          1
n_minage.1989    42.4426       1 ;22.4426
n_minage.1990    37.6845       1
n_minage.1991    54.2067       1
n_minage.1992    89.8773       1
n_minage.1993    60.867        1 ;115.867
n_minage.1994    60.185        1 ;106.185
n_minage.1995    61.5676       1
n_minage.1996    41.7543       1
n_minage.1997    69.3211       1
n_minage.1998    84.7229       1
n_minage.1999    48.2519       1
n_minage.2000    57.9294       1

;Mean length of minimum-age fish at start of year x
l_minage.1984    35.8          1
l_minage.1985    50.3          1 ;40.3
l_minage.1986    44.4          1 ;34.4
l_minage.1987    41.8          1 ;31.8
l_minage.1988    39.7          1 ;29.7
l_minage.1989    44.7          1 ;34.7
l_minage.1990    39.4          1
l_minage.1991    41.6          1
l_minage.1992    41.3          1
l_minage.1993    35.9          1
l_minage.1994    30.5          1
l_minage.1995    29.9          1
l_minage.1996    28.1          1
l_minage.1997    28.0          1
l_minage.1998    28.7          1
l_minage.1999    29.0          1
l_minage.2000    28.7          1
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;Standard deviation of mean length of minimum-age fish at start of year x
d_minage.1984    4.3           0
d_minage.1985    5.1           0
d_minage.1986    4.4           0
d_minage.1987    3.5           0
d_minage.1988    3.1           0
d_minage.1989    3.4           0
d_minage.1990    6.8           0
d_minage.1991    5.8           0
d_minage.1992    6.5           0
d_minage.1993    4.4           0
d_minage.1994    5.0           0
d_minage.1995    5.9           0
d_minage.1996    5.0           0
d_minage.1997    3.9           0
d_minage.1998    4.4           0
d_minage.1999    4.2           0
d_minage.2000    4.1           0

;Quarterly natural residual mortality of mature fish (in 3 length intervals)
mat.mort1        0.05          0 ;Quart. mat mortality length 1
mat.mort2        0.05          0 ;Quart. mat mortality length 2
mat.mort3        0.05          0 ;Quart. mat mortality length 3

;Number of mature fish in startyear of age x (10^7)
mat.n_age4       0.94          0
mat.n_age5       0.81          0
mat.n_age6       1.49          0
mat.n_age7       2.53          0
mat.n_age8       2.77          0
mat.n_age9       0.44          0
mat.n_age10      0.11          0
mat.n_age11      0.05          0
mat.n_age12      0.02          0

;Mean length (cm) of mature fish in startyear at age x
mat.l_age4       51.0          0
mat.l_age5       59.6          0
mat.l_age6       71.1          0
mat.l_age7       79.0          0
mat.l_age8       88.2          0
mat.l_age9       97.3          0
mat.l_age10      100.0         0
mat.l_age11      105.0         0
mat.l_age12      110.0         0

;Standard Deviation of mean length of mature fish in startyear at age x
mat.d_age4       1.06835       0
mat.d_age5       1.05602       0
mat.d_age6       1.01149       0
mat.d_age7       1.82767       0
mat.d_age8       2.56627       0
mat.d_age9       4.00303       0
mat.d_age10      7.15294       0
mat.d_age11      7.33135       0
mat.d_age12      9.03202       0
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;fleet names
;11 dan  - Danish seine
;12 gil  - Gillnet
;13 hnd  - Handline
;14 lng  - Longline
;15 nor  - Norwegian trawl
;16 rus  - Russian trawl
;17 trd  - Third countries
;18 ovr  - Overfishing

;Catches, selection parameters
;05 slope
;06 l50

;Danish seine
dan.slope        0.0607076     1 ;Slope of selection curve
dan.l50          38.9944       1 ;L50 of selection curve 48.9944
dan.f1983        0.0587794     1 ;Partial F
dan.f1985        0.0219238     1
dan.f1986        0.0221278     1
dan.f1987        0.0104634     1
dan.f1988        0.0181976     1
dan.f1989        0.0176029     1
dan.f1990        0.00826144    1
dan.f1991        0.00635922    1
dan.f1992        0.00595641    1
dan.f1993        0.0086952     1
dan.f1994        0.0133794     1
dan.f1995        0.0230026     1
dan.f1996        0.0550674     1
dan.f1997        0.0704295     1
dan.f1998        0.0732092     1
dan.f1999        0.0466631     1

;Gillnet
gil.p0           0.0          0 ;Parameters for bell-shaped selection curve
gil.p1           0.2           1 ;
gil.p2           1.0           0 ;
gil.p3           0.03          1 ;
gil.p4           0.1           1 ;
gil.f1983        0.5           1 ;Partial F
gil.f1985        0.45          1
gil.f1986        0.3           1
gil.f1987        0.2           1
gil.f1988        0.3           1
gil.f1989        0.3           1
gil.f1990        0.0946737     1
gil.f1991        0.1           1
gil.f1992        0.074         1
gil.f1993        0.12          1
gil.f1994        0.13          1
gil.f1995        0.27          1
gil.f1996        0.30          1
gil.f1997        0.3           1
gil.f1998        0.2           1
gil.f1999        0.2           1
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;Handline
hnd.slope        0.0405734     1 ;Slope of selection curve
hnd.l50          53.0          1 ;L50 of selection curve
hnd.f1983        0.0756208     1 ;Partial F
hnd.f1985        0.0800624     1
hnd.f1986        0.0642485     1
hnd.f1987        0.0177128     1
hnd.f1988        0.0122281     1
hnd.f1989        0.0238063     1
hnd.f1990        0.0146502     1
hnd.f1991        0.0149757     1
hnd.f1992        0.015031      1
hnd.f1993        0.0211967     1
hnd.f1994        0.0236036     1
hnd.f1995        0.0138551     1
hnd.f1996        0.0140966     1
hnd.f1997        0.0230576     1
hnd.f1998        0.0360075     1
hnd.f1999        0.0518532     1

;Longline
lng.slope        0.0403351     1 ;Slope of selection curve
lng.l50          43.0          1 ;L50 of selection curve 53.0
lng.f1983        0.1           1 ;Partial F
lng.f1985        0.0603888     1
lng.f1986        0.118796      1
lng.f1987        0.13          1
lng.f1988        0.15          1
lng.f1989        0.0994491     1
lng.f1990        0.0181273     1
lng.f1991        0.0153615     1
lng.f1992        0.0146599     1
lng.f1993        0.0228395     1
lng.f1994        0.0411349     1
lng.f1995        0.062821      1
lng.f1996        0.0752675     1
lng.f1997        0.101545      1
lng.f1998        0.112065      1
lng.f1999        0.109276      1

;Norwegian trawl
nor.slope        0.0395656     1 ;Slope of selection curve
nor.l50          42.0          1 ;L50 of selection curve 52.0
nor.f1983        0.1           1 ;Partial F
nor.f1985        0.05          1
nor.f1986        0.13          1
nor.f1987        0.425498      1
nor.f1988        0.14          1
nor.f1989        0.1           1
nor.f1990        0.04          1
nor.f1991        0.02          1
nor.f1992        0.03          1
nor.f1993        0.05          1
nor.f1994        0.07          1
nor.f1995        0.07          1
nor.f1996        0.07          1
nor.f1997        0.15          1
nor.f1998        0.18          1
nor.f1999        0.10          1
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;Russian trawl
rus.slope        0.0564928     1 ;Slope of selection curve
rus.l50          40.1759       1 ;L50 of selection curve 50.1759
rus.f1983        0.0444292     1 ;Partial F
rus.f1985        0.05          1
rus.f1986        0.1           1
rus.f1987        0.1           1
rus.f1988        0.17          1
rus.f1989        0.14          1
rus.f1990        0.03          1
rus.f1991        0.07          1
rus.f1992        0.05          1
rus.f1993        0.06          1
rus.f1994        0.1           1
rus.f1995        0.13          1
rus.f1996        0.18          1
rus.f1997        0.36          1
rus.f1998        0.24          1
rus.f1999        0.22          1

;Overfishing
ovr.slope        0.04          0 ;Slope of selection curve
ovr.l50          52            0 ;L50 of selection curve
ovr.f1983        0             0 ;Partial F
ovr.f1985        0             0
ovr.f1986        0             0
ovr.f1987        0             0
ovr.f1988        0             0
ovr.f1989        0             0
ovr.f1990        0.03          0
ovr.f1991        0.07          0
ovr.f1992        0.08          0
ovr.f1993        0.03          0
ovr.f1994        0.015         0
ovr.f1995        0             0
ovr.f1996        0             0
ovr.f1997        0             0
ovr.f1998        0             0
ovr.f1999        0             0

;survey names
;1 lofac   - Lofoten acoustic (1985-2000)
;2 ba1tr   - Barents Sea trawl (1983-1993)
;3 ba1ac   - Barents Sea acoustic (1983-1993)
;4 svatr   - Svalbard bottom trawl survey (1987-1999) not in use at present
;5 ba2ac   - Barents Sea acoustic (1994-2000)
;6 ba2tr   - Barents Sea trawl (1994-2000)
;7 rustr   - Russian autumn bottom trawl survey - 1982-1999
;8 nortr   - Norwegian summer (autumn) survey - bottom trawl (1995-1999)
;Survey catchability parameter names
;04 cbt    - Catchability
;01 b0     - Exponent (for power fit) or constant (for linear fit)
;02 slope  - Slope
;03 l50    - L50
;Barents Sea trawl (1983-1993)
;ba1tr.cbt        0.4           1 ;Catchability
;ba1tr.b0         1             0 ;b0
;ba1tr.slope      0.05          1 ;Slope
;ba1tr.l50        20.0          1 ;L50
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;Barents Sea trawl (1994-2000)
ba2tr.cbt        0.45344       1 ;Catchability
ba2tr.b0         1             0 ;b0
ba2tr.slope      0.05          0 ;Slope
ba2tr.l50        5             0 ;L50

;Lofoten acoustic (1985-2000)
lofac.cbt        0.5           1 ;Catchability
lofac.b0         1             0 ;b0
lofac.slope      0.05          0 ;Slope
lofac.l50        5             0 ;L50

;Barents Sea acoustic (1983-1993)
;ba1ac.cbt        0.666635      1 ;Catchability
;ba1ac.b0         1             0 ;b0
;ba1ac.slope      0.05          1 ;Slope
;ba1ac.l50        20.0          1 ;L50

;Barents Sea acoustic (1994-2000)
ba2ac.cbt        0.43503       1 ;Catchability
ba2ac.b0         1             0 ;b0
ba2ac.slope      0.05          0 ;Slope
ba2ac.l50        5             0 ;L50

;Russian autumn bottom trawl survey - 1982-1999
rustr.cbt        0.2           1 ;Catchability
rustr.b0         1             0 ;b0
rustr.slope      0.141564      1 ;Slope
rustr.l50        1             1 ;L50

;Norwegian summer (autumn) survey - bottom trawl (1995-1999)
nortr.cbt        0.62168       1 ;Catchability
nortr.b0         1             0 ;b0
nortr.slope      0.05          0 ;Slope
nortr.l50        5             0 ;L50
```